Astronautics

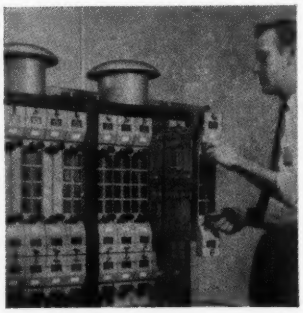
A PUBLICATION OF THE AMERICAN ROCKET SOCIETY

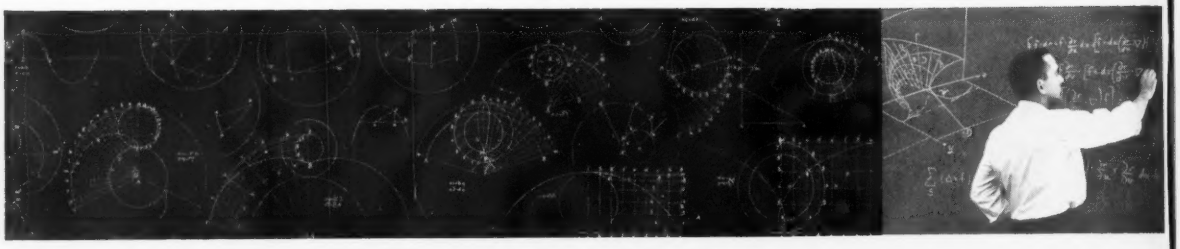
MAY 1961

DATA FROM SPACE—Progress and Plans

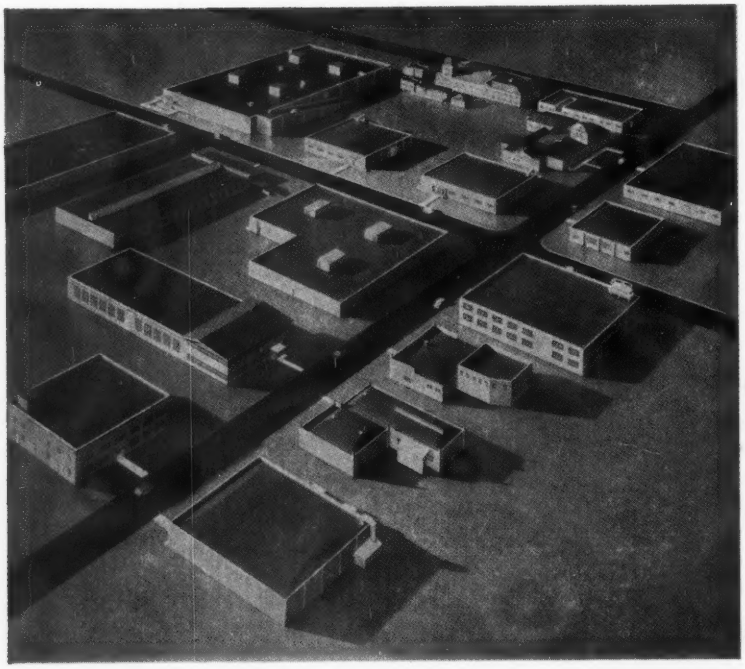
LIBRASCOPE COMPUTER FACILITIES

Shown below is a composite view of Librascope's facilities where a variety of computer systems are currently in different stages of design and production. Some are strategically involved with national defense...others deal with business and industrial process control. Each is uniquely designed to answer a particular need. The success of these systems illustrates the value of Librascope's engineering philosophy: A decentralized organization of specialized project teams responsible for assignments from concept to delivery...and backed up by excellent research, service, and production facilities. For your computer requirements, call on the company whose breadth of diversification in computer technology is unsurpassed. ■ Librascope Division, General Precision, Inc., 808 Western Avenue, Glendale, Calif. For career opportunities write to John Schmidt, Engineering Employment. ■





computers that pace man's expanding mind



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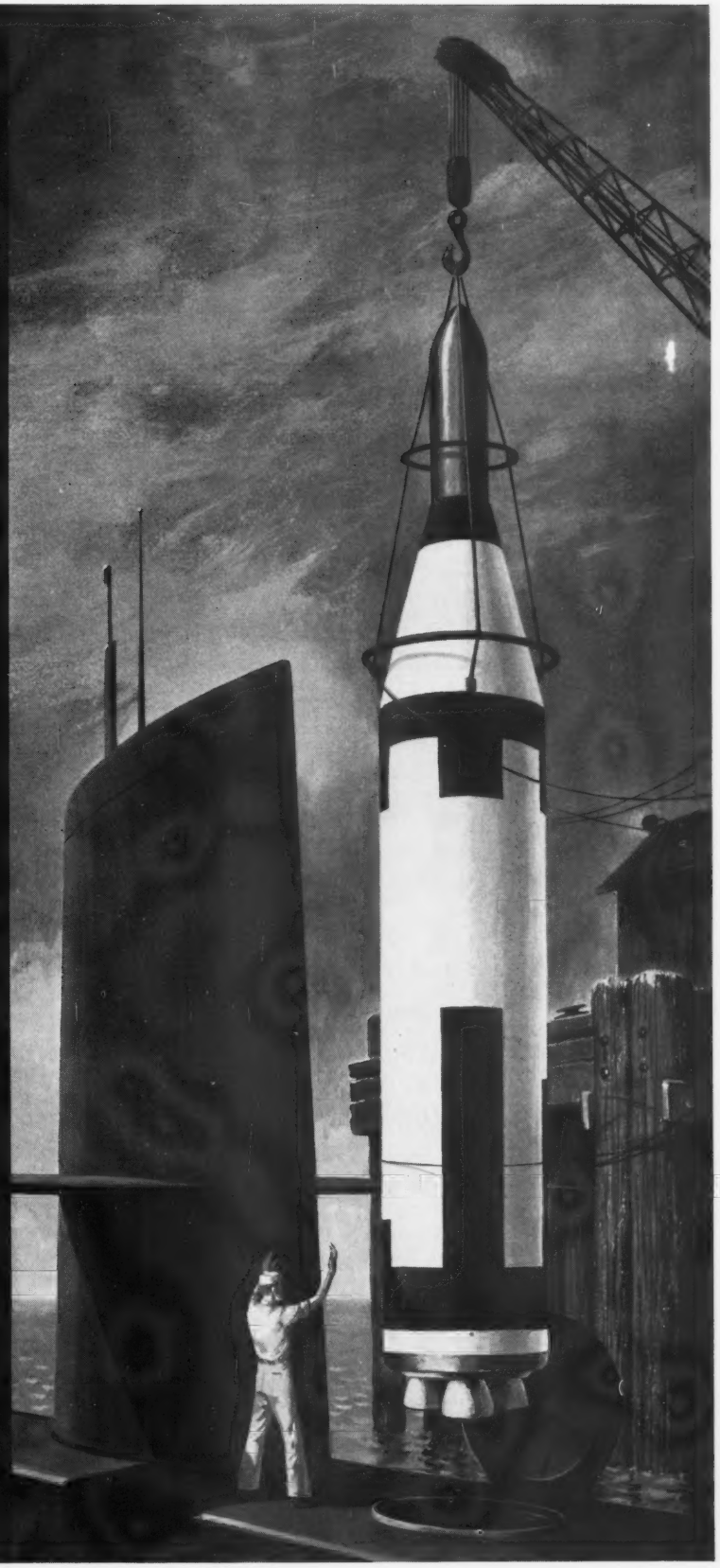

Engineers, scientists—investigate outstanding opportunities at Aerojet

from the reaches of space

Unretouched time exposure shows Echo I communications satellite (long line) crossing heavens right to left. Shorter lines are stars "in motion."

to the depths of the sea

Actual undersea photo of telephone cable off coast of Florida.

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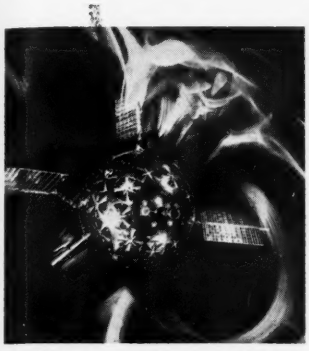

COVER: In the coming years data flashing from space and round the globe will remake our image of earth, the universe, even ourselves. Complex equipment, like this unsung Pioneer VI probe, wreathed in varicolored light from a time-exposure Air Force photo, has pushed the electronics art to set the data flowing in diverse channels. (ASTRO cover plaques 11 × 12 in. are available from ARS Headquarters at $2.00 each.)

Astronautics

A PUBLICATION OF THE AMERICAN ROCKET SOCIETY INC.

Vol. 6 No. 5 May 1961

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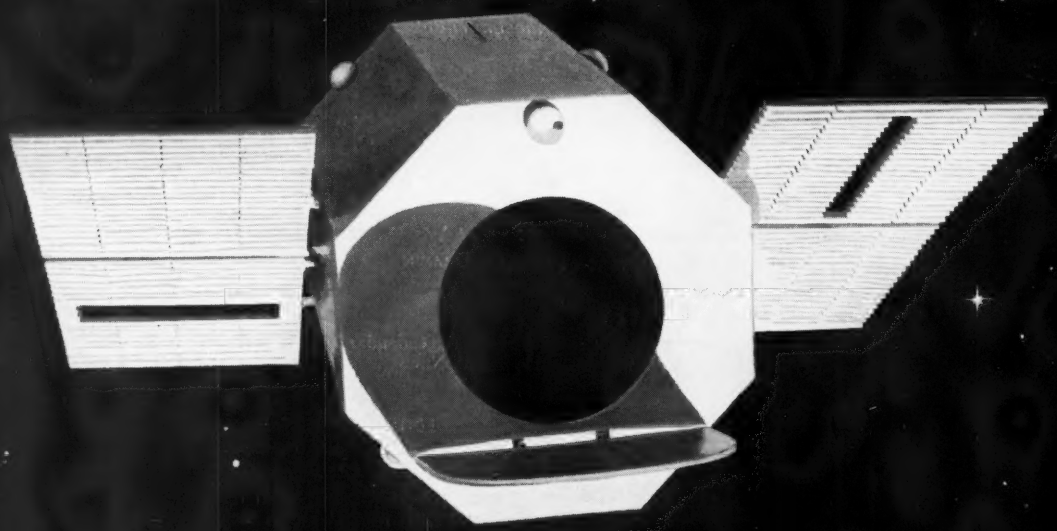
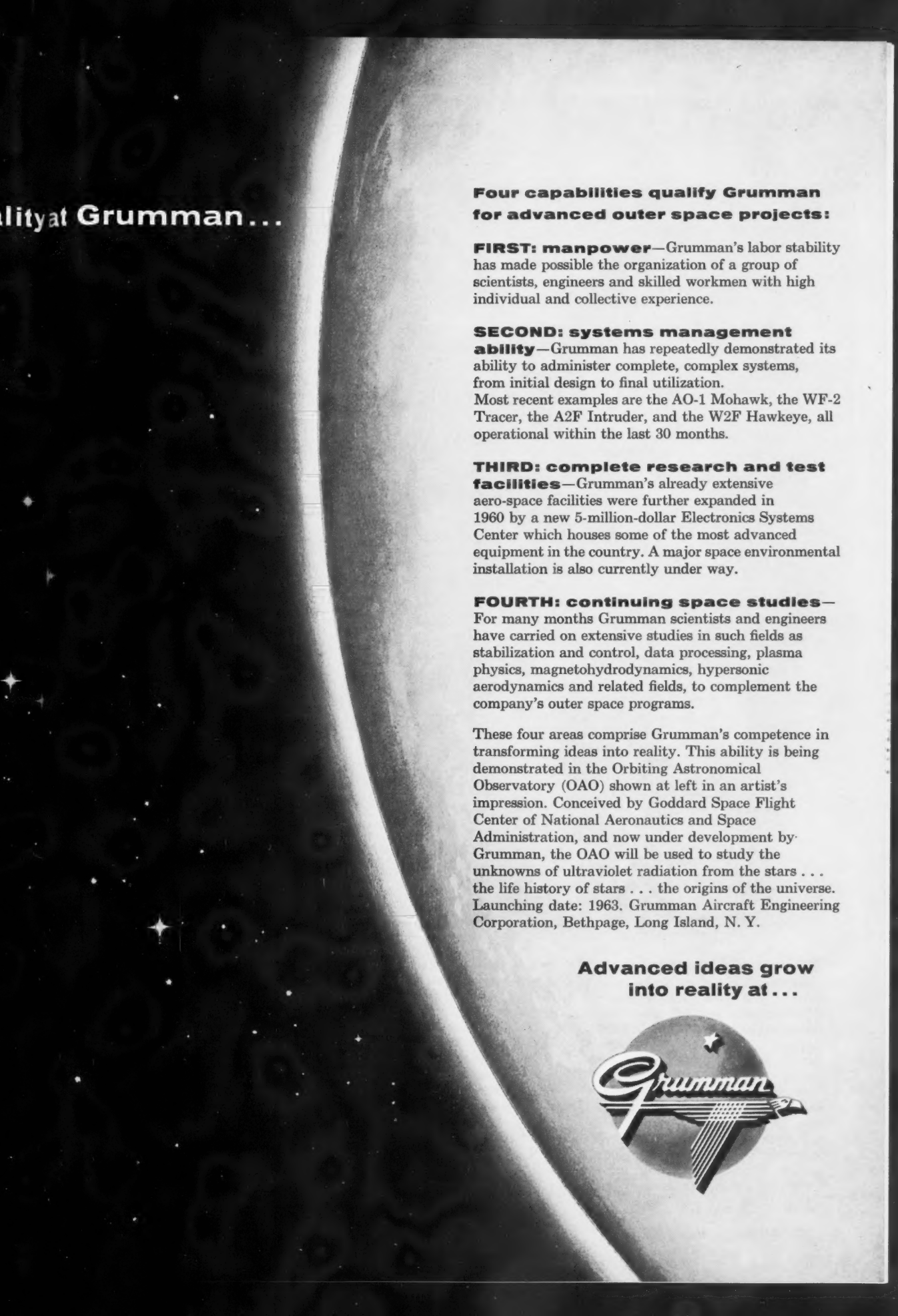
How advanced ideas grow into reality





Four capabilities qualify Grumman for advanced outer space projects:

FIRST: manpower—Grumman's labor stability has made possible the organization of a group of scientists, engineers and skilled workmen with high individual and collective experience.

SECOND: systems management ability—Grumman has repeatedly demonstrated its ability to administer complete, complex systems, from initial design to final utilization.
Most recent examples are the AO-1 Mohawk, the WF-2 Tracer, the A2F Intruder, and the W2F Hawkeye, all operational within the last 30 months.

THIRD: complete research and test facilities—Grumman's already extensive aero-space facilities were further expanded in 1960 by a new 5-million-dollar Electronics Systems Center which houses some of the most advanced equipment in the country. A major space environmental installation is also currently under way.

FOURTH: continuing space studies—For many months Grumman scientists and engineers have carried on extensive studies in such fields as stabilization and control, data processing, plasma physics, magnetohydrodynamics, hypersonic aerodynamics and related fields, to complement the company's outer space programs.

These four areas comprise Grumman's competence in transforming ideas into reality. This ability is being demonstrated in the Orbiting Astronomical Observatory (OAO) shown at left in an artist's impression. Conceived by Goddard Space Flight Center of National Aeronautics and Space Administration, and now under development by Grumman, the OAO will be used to study the unknowns of ultraviolet radiation from the stars . . . the life history of stars . . . the origins of the universe. Launching date: 1963. Grumman Aircraft Engineering Corporation, Bethpage, Long Island, N. Y.

Advanced ideas grow into reality at . . .

Grumman

Astro notes

YURI GAGARIN— NAVIGATOR, THE VOSTOK

• These few simple words—Yuri Gagarin, Navigator, the Vostok—wrap up a long story. The Tass news announcement adjacent describes as well as anything the facts of the case. The Russians fulfilled the promise of their lead in rocket-booster development with audacity —announcing man in space while he was there.

• In a press conference at the USSR Academy of Sciences two weeks before the flight of the Vostok, Russian scientists provided background to the Soviet man-in-space program. In an opening speech Academician A. V. Topchiyev stated that the USSR's direct preparations for carrying out a manned space flight began with the successful launching of the first large spaceship in May 1960. "As to technical possibilities," he said, "such a flight could have already taken place last year (meaning in 1960)." Topchiyev implied that manned orbital flight awaited the analysis of the numerous biological specimens flown on the fourth and fifth 5-ton spaceships.

• Academician N. M. Sisakyan shed some light on the Russians' biomedical work. "The main conclusion derived from the numerous and varied data from biological research," he stated, "is that the conditions of the flight of spaceships along a circular orbit below extra-terrestrial radiation belts do not substantially affect the vital activity of the organisms and do not cause any protracted or considerable disorders in basic physiological functions. At the same time it has been established that the conditions of space flight can influence the development and reproduction of certain organisms and cause hereditary changes in them. Cell division and growth of the shoots of wheat, peas, and corn proceeded considerably faster than in control samples. The greatest increase in growth was observed in some varieties of ray fungi. However, the investigation of a culture of a radio-sensitive strain of ray fungi showed that its vitality was several times lower than that of the control samples. We are now working out protective means that would completely eliminate the unfavorable effects connected with changes in the physiological functions of organisms."

Statement issued by Tass, Soviet press agency, in Moscow during the flight of the Vostok:

The world's first satellite spaceship Vostok, with a man on board, was placed in an around-the-earth orbit in the Soviet Union on April 12, 1961.

The pilot space navigator of the Vostok is a citizen of the USSR, Flight Maj. Yuri Alekseyevich Gagarin.

The launching of the multistage space rocket was successful, and after attaining the first escape velocity and the separation of the last stage of the carrier-rocket, the spaceship went into free flight on an around-the-earth orbit.

According to preliminary data, the period of the revolution of the satellite spaceship around the earth is 89.1 min. The minimum distance from the earth (at perigee) is 175 km [109½ mi] and the maximum (at apogee) is 302 km [187¾ mi]. The angle of inclination of the orbit plane to the equator is 65 deg 4 min.

The spaceship with the navigator weighs 4725 kilograms [about 5 tons], excluding the weight of the final stage of the carrier.

Bilateral radio communications have been established and are maintained with Space Navigator Gagarin. The frequency of the short-wave transmitters on board are 9019 mc and 20,006 mc, and in the ultra-short-wave range 143.625 mc.

The condition of the navigator in flight is observed by means of radio telemetric and television systems.

Space Navigator Gagarin withstood satisfactorily the placing of the satellite ship Vostok into orbit, and at present feels well. The systems insuring the necessary vital conditions in the cabin of the spaceship are functioning normally.

The spaceship, with Navigator Gagarin on board, is continuing its flight in orbit.

• Project Mercury, considering the handicap under which it began, stands not too distant in days from the flight of the Vostok. But putting together the apparent preciseness of Soviet astrodynamics, the qualitative response of Gagarin to weightlessness and the other conditions of orbital flight, the established performance of the Vostok spacecraft, and the information coming from these biomedical studies, it looks as if the Russian lead in manned space flight will stretch out over the next three years, and that we must wait the development of Saturn and the launching of manned orbital laboratories under the Apollo program to hit the Russian's stride in manned space flight.

MAN IN SPACE

• NASA accelerated the development schedule for its Apollo advanced man-in-space program approximately 1 yr by its decision last month to separate the orbiting laboratory from the circumlunar mission. The agency is now aiming at its first three-man laboratory in 1965 using the Saturn C-1 booster. Under the original concept, a single modular vehicle was to be developed for both missions. The two were separated when it was realized that the orbiting laboratory could provide detailed information on prolonged weightlessness and radiation—areas of vital importance to the final design of the circumlunar vehicle.

• Although the space agency spurred the Apollo program by administrative action of its own, there was no move by the Administration to step up the project by providing funds for the initiation of hardware development in fiscal 1962. The Eisenhower funding level for Apollo ($29.5 million) was left unchanged.

• Barring further setbacks, the initial flight of a U.S. astronaut in a Redstone-boosted Mercury space

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capsule is slated for early May. It was delayed by a malfunction of the Little Joe VI capsule escape test in mid-March, necessitating another Little Joe test in April. The trouble was identical to that which spoiled Little Joe V last fall: Premature ignition of the escape rockets before capsule release from the booster vehicle. NASA recovered the capsule and returned it to McDonnell to be reconditioned for Little Joe VII.

• At the behest of Marshall Space Flight Center, a special test flight of the Redstone booster was conducted with an inert boilerplate capsule to prove out all the modifications made in the booster to improve it for manned flights. This was a perfect flight, and it allayed uneasiness over the fact that minor bugs appeared in the MR-1 and MR-3 tests. Two procedures were employed in the latest flight to prevent the Redstone control system from reacting to oscillations in the elongated structure of the vehicle. These included an electrical filter in the attitude-control system to damp out undesirable signals and the addition of a thick undercoating to the upper part of the Redstone instrument compartment to absorb vibrations.

• Clark T. Randt resigned as director of NASA's Office of Life Science Programs when the program he advocated in space biology and biomedicine was not approved. The AF brought heavy pressure to bear against a NASA program in human factors and biology.

• With NASA test pilot Joe Walker at the controls, the X-15, powered by the 57,000 lb-thrust Thiokol engine, rocketed to an altitude of 165,000 ft. It attained a maximum speed of 2590 mph during the flight and subjected Walker to 2 min of weightlessness.

• The AF has drastically modified an F-100F fighter to simulate the steep-angle, high-speed landings characteristic of rocket aircraft like the X-15 and Dynasoar in an effort to eliminate the long-runway requirement for such craft. The modified F-100F has been equipped with a thrust reverser, in place of its afterburner and drag chute, and a speed brake three times the area of its regular brake. The test pilot will operate the thrust reverser at about 6000-ft altitude to bring the plane down steeply. Is landing speed will be about 230 mph instead of the normal F-100F touchdown speed of 155 mph.

SATELLITES

• The Navy has not been getting the orbits it needs in the Transit program (see R. B. Kershner's article on page 30). The Pacific Missile Range can place the Navy's Transit satellites in orbits of 70-deg inclination without traversing land, but there is no Thor-Able-Star launch facility at PMR sites. Until one is constructed, the Navy will have to content itself with low-latitude Transit orbits fired from Cape Canaveral.

• NASA's Goddard Space Flight Center, dedicated recently (see page 27), is considering a new solar-observatory satellite about halfway between the 350-lb Orbiting Solar Observatory (now scheduled to fly in late summer) and the 3500-lb Orbiting Astronomical Observatory to fly in 1963 (see page 36). The intermediate satellite could use the power supply, stabilization, telemetry, and related systems developed for Nimbus and Pogo, and it would have less strenuous pointing and slewing requirements.

• The Navy may try a double piggyback shot with its next Transit: A Greb solar-powered satellite devised by the Naval Research Laboratory to detect soft X-rays, and a smaller solar-powered radiation satellite, called Injun, which James Van Allen has built. The malfunction of Transit III-B may delay the double piggyback attempt, so the Army may have another opportunity to orbit its Secor geodetic experiment.

• NASA was scheduled to pioneer a brand new field of scientific satellite observations by orbiting its first "gamma ray telescope" in April. The 82-lb S-15 will use coincidence-counting techniques to register impacts by cosmic rays, and sun and earth sensors will provide continuous information as to the satellite's orientation. A slow tumbling motion imparted to the satellite will gradually permit it to map the entire sky, and the data will be stored on magnetic tape and readout to interrogating ground stations.

• Overlooked by many was the significance of the orbital parameters for Samos II. The latter was fired into a retrograde orbit 7 deg west of south—a luxury which the AF can afford when it uses the Atlas-Agena-B launching combination in place of the Thor-Agena-B. In launching to the west, the vehicle not only loses all advantage of the earth's spin, but must make up for any deficit with extra energy in the rocket.

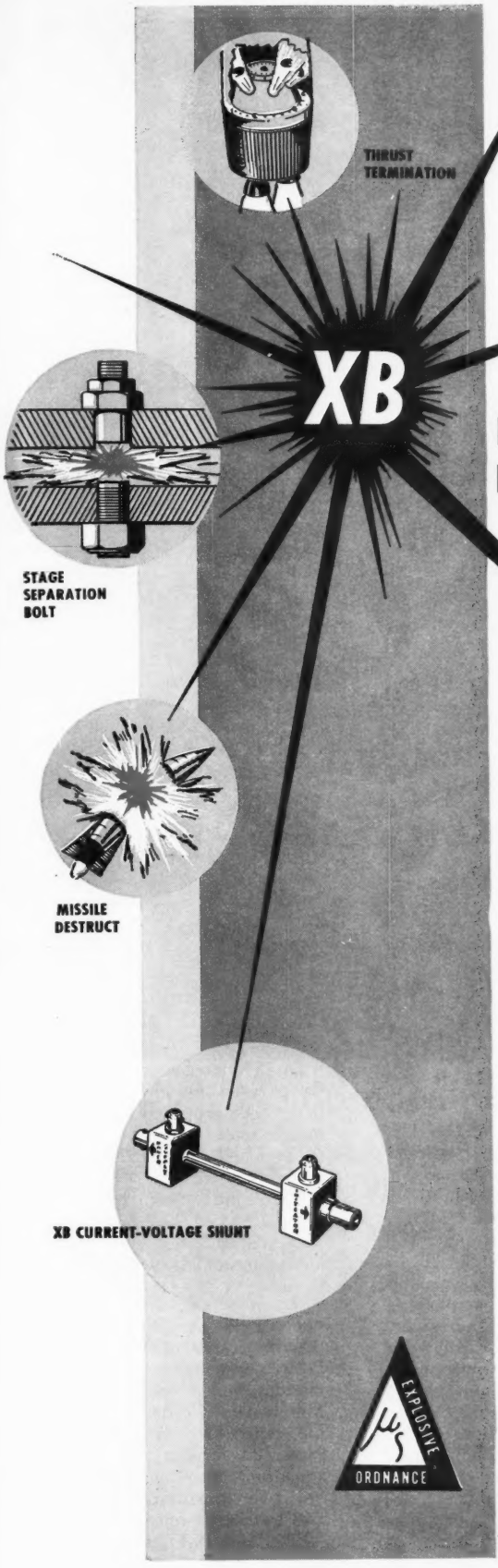
• The AF's run of bad luck continued with Discoverer XXII, which failed to orbit because of a malfunction in the restartable Agena-B second stage. It was the second Discoverer failure in the last seven shots. Three of these shots were scheduled to return capsules and two succeeded. Result of the troubles has been an indefinite postponement of the AF monkey shot.

SPACE SCIENCE

• Satellite design will be aided by data from NASA's 78-lb magnetometer-plasma probe launched 112,500 mi into cislunar space recently by a Thor-Delta booster. During its 60 hr of battery life, the probe (incongruously named Explorer X) transmitted a wealth of measurements from its rubidium-vapor magnetometer (sensitive to 0.01 gamma), two fluxgate magnetometers (sensitive to 0.5 gamma) and a plasma probe capable of detecting low-energy ions. A quick look at the telemetered data showed that the magnetic fields encountered between 60,000 mi and apogee were "considerably stronger than expected."

• Electronic engineers may solve the riddles of Venus long before the rocketeers if an ambitious program of the Jet Propulsion Laboratory is successful. A JPL crew at Goldstone, Calif., has succeeded in bouncing a 2388 mc signal off of Venus with an 85-ft transmitter dish and 10 kw of power. The echo has been detected by the 85-ft receiving antenna using both a ruby-crystal maser and a parametric amplifier to reduce noise. JPL hopes to determine during a two-month experiment whether Venus rotates, its speed of rotation, orientation of spin axis, surface characteristics and a tighter value for the Astronomical Unit.

• General Electric is studying super-strength composite materials expected to have three or four times the tensile strength of conventional materials. It will try to use sapphire "whiskers" (see last month's cover) grown from pure aluminum as "reinforcement" for standard aluminum metal. The enormous strength of the pure crystal whiskers may make possible a composite material strength-to-weight ratio of 600,000 in. at 2000 F, according to the company. GE just demonstrated the continuous production of uniform whiskers and the bonding of whiskers to a metal, silver. The whisker field is suddenly rich for mining.



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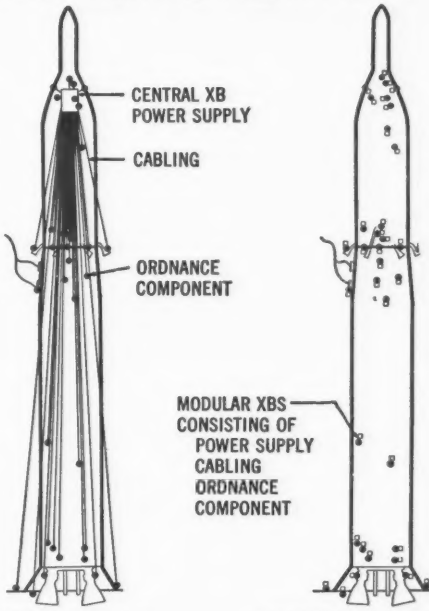
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PROPULSION

• The Administration asked Congress for a $125.7-million boost for NASA in fiscal 1962, practically all of it for accelerated development of new rocket propulsion capability. The biggest chunk of the additional money was asked for the C-2 Saturn; an extra $78 million will permit its first flight test in 1964, and accelerate by one year (to 1966) the flight of the seventh vehicle marking its operational status. Other NASA increases included $26 million for Centaur launch vehicles, $9 million for the F-1 engine of 1.5-million-lb thrust, and 4 million for the Rover nuclear rocket program. All told, NASA is seeking $1,235 million for fiscal 1962, and it expects to spend $1,050,000,000 during the year.

• In an interesting move, the space agency ordered a major modification in the Saturn S-IV stage which will increase its thrust from 70,000 to 90,000 lb. This will be accomplished by switching from four LR-117 engines of 17,500 lb each to six LR-115 engines of 15,000 lb each. The engines, under development by Pratt & Whitney, use liquid oxygen and liquid hydrogen as propellants. NASA said the switch would not delay the 1963 test date originally set for the S-IV stage, under development by Douglas Aircraft. It will be the second stage of the three-stage C-1 Saturn and the third stage of the four-stage C-2. The Saturn C-2 will be able to orbit 45,000-lb payloads against 19,000 lb for C-1.

• Like a promise for the future, the giant F-1 engine roared to a record thrust of 1.64-million lb in a 13-sec run at the Edwards rocket-testing site early in April. The firing tested a full-size tubular-wall thrust chamber. Rocketdyne and Marshall SFC reported that the test was begun and terminated as programmed.

• Seven firms responded to an invitation from the NASA-AEC Nuclear Propulsion Office to submit proposals on research and development of a nuclear rocket engine: Aerojet-General, Rocketdyne, American Metal Products, Pratt and Whitney, United Aircraft, Thiokol Chemical, Westinghouse, and General Electric.

• Selection of a contractor, although it will be based on a company's capability to carry out the entire nuclear rocket engine development program, will result initially only in the award of a contract for the first phase of the program. This phase will include assistance to Los Alamos Scientific Laboratory in the conduct of the Kiwi-B test program, conduct of a preliminary design of the flight engine, formulation of an engine development program, and performance of certain research and development tasks on non-nuclear components.

• United Technology Corp. dedicated its research and development center south of San Francisco last month, and showed for the occasion a full-scale model of the 250,000-lb-thrust conical segmented solid rocket that it will test soon in a demonstration for NASA. The UTC facilities include what the company calls the world's largest in-ground solid-propellant curing ovens and a test stand that can handle motors of 2-million-lb thrust.

• NASA's Marshall SFC took its first step toward studying construction of an off-shore launch facility for heavy space vehicles, such as Saturn with a nuclear upper stage. Such a facility could be built off Cape Canaveral. Marshall has received 12 proposals for conducting preliminary design studies.

• Systems contractors will submit initial proposals on the Saturn S-II stage to Marshall SFC by the 11th of this month. The S-II stage is to be the second stage of the Saturn C-2, and will be powered by four J-2 liquid-hydrogen liquid-oxygen engines, each of which will develop 200,000 lb of thrust. Rocketdyne is developing the J-2 for NASA. The whole S-II stage will by itself tower 74 ft and measure $21^1/_2$ ft in diam.

• In a more exotic area, NASA is negotiating a $100,000 contract with General Electric for a 12-month study of the feasibility of a magnetohydrodynamic (MHD) engine for deep-space probes. The unit would form a plasma by a microwave discharge in a gas, and the plasma would be accelerated magnetically through a nozzle. The agency also gave GE and Avco $50,000 contracts to perform 6-month studies of optimum applications for the small arc-jet engines they are developing under separate NASA contract. Such units, used with nuclear reactors, might be useful maintaining large communication satellites in synchronous earth orbits over long periods of time.

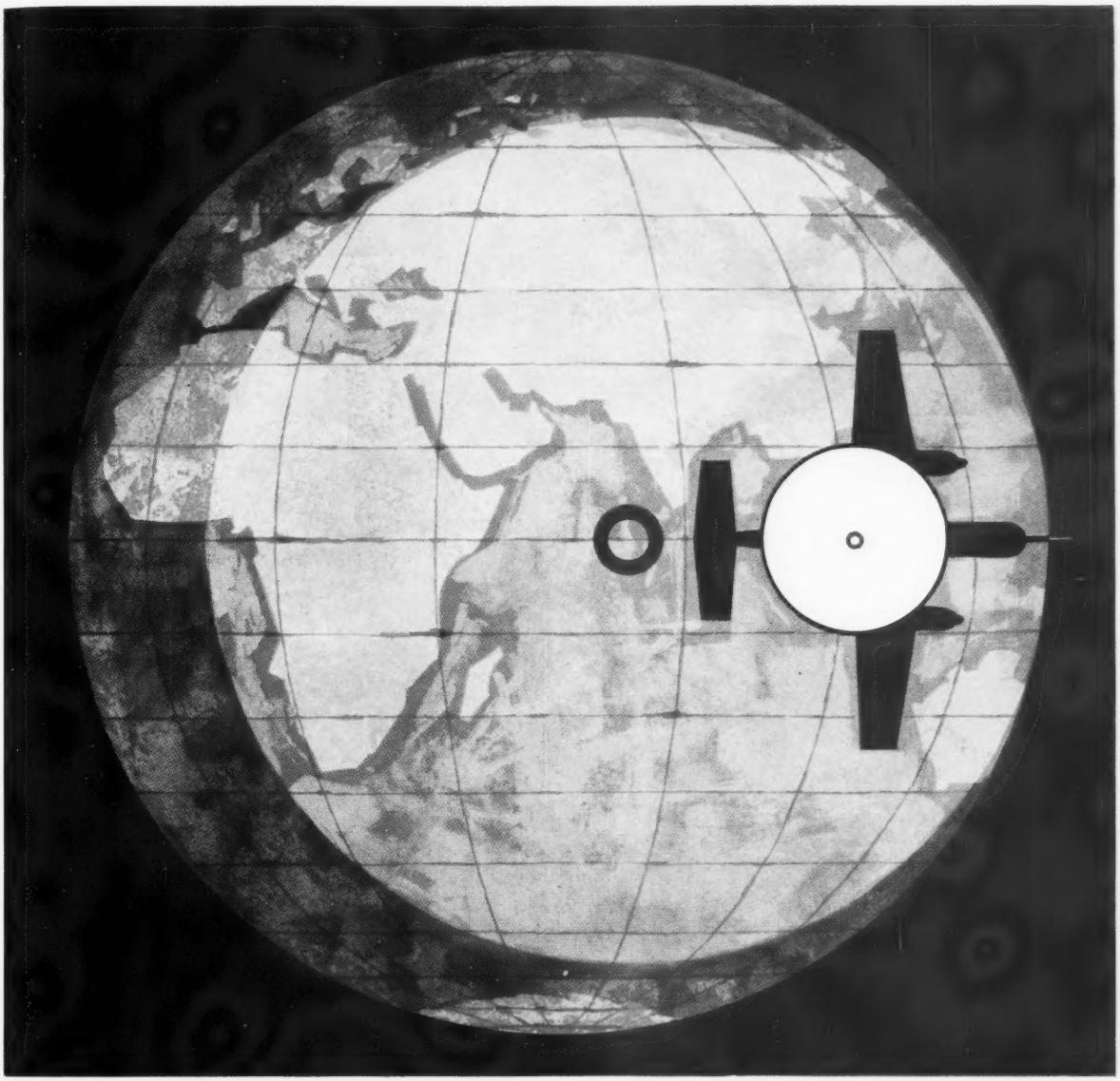
• Interest in the next generation of big boosters is by no means confined to liquid systems. Aerojet-General proposes a 140-in.-diam segmented-solid system capable of orbiting 24,500 lb. It has successfully tested 100-in.-diam center segments and it is looking for an AF follow-on contract to perform preliminary tests of a rocket consisting of several 100-in. segments. It proposes liquids for thrust-vector control, eliminating the need for movable nozzles, steering jets, and other paraphernalia.

WEAPONS

• Weapons by ball lightning are at last receiving serious U.S. military attention. The AF gave Raytheon an $89,356 contract to investigate the generation and projection of "high-energy spherical plasmoids," i.e., ball lightning. Raytheon was one of seven companies bidding on the study, indicating a growing awareness of plasma physics as a source of new weapons. The Russians, incidentally, have long been interested in the phenomenon. No less a scientist than Peter Kapitza over five years ago suggested that ball lightning is produced and sustained during its brief, antic lifetime by radio frequency energy from lightning discharges. Also, Eugene Sanger commented on the possibility of using a plasma as a weapon in his 1959 IAF paper.

• The U.S. will build a force of 1298 ballistic missiles of intercontinental range by 1965, according to the plan presented Congress by the Kennedy Administration. This is an 18% increase over the Eisenhower plan for the same target date. The projected U.S. ballistic-missile force (exclusive of Skybolt air-launched weapons) will consist of 600 Minuteman ICBMs in underground silos, 464 Polaris missiles aboard 29 submarines, 126 Atlas ICBMs, and 108 Titans of both the storable and nonstorable variety.

• The Pentagon's increased missile power consists of 160 additional Polaris weapons on 10 new submarines, and a net increase of 60 Minuteman ICBMs resulting from the switch of three mobile squadrons (90 missiles) to three silo squadrons (150 missiles). The last two squadrons of Titan IIs (18 missiles) projected for Griffiss AFB, Rome, N.Y., were eliminated at a saving of $270 million. The



Brunswick Rotodomes - New Eyes and Ears of the Fleet!

Grumman Hawkeye carrier-based A.E.W. aircraft with a Brunswick-built rotodome gives new early warning capability to the Navy.

The Dalmo-Victor Division of Textron Inc. assigned Brunswick the task of fabricating the newest and most sophisticated of rotodomes. Brunswick's vast experience in fabricating large plastic-metal structures of sandwich construction assured the customer and the Navy of receiving a completely reliable product.

This large, complicated structure is another example of Brunswick's capability in the field of reinforced plastics and metal honeycomb. Whether the requirement be for a small structural unit such as a missile radome operating at high frequency, a large composite structure such as the rotodome, large reflectors or ground domes, you can count on Brunswick's project experience to accomplish your most difficult assignments.

In addition, Brunswick offers imaginative scientists and engineers to provide a searching approach to materials and fabrication techniques and electronic know-how. Complete testing and quality control facilities assure the success of all programs.

Interested engineers will find it rewarding to discuss career futures with Brunswick.

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net result is an increase of 202 missiles of intercontinental capability by 1965.

• The New Frontier's commitment to ballistic missiles did not extend to manned aircraft. It wiped out completely the Aircraft Nuclear Propulsion program (cited by Vice Adm. Hayward recently as a perfect example of how *not* to conduct a development), including both the direct (GE) and the indirect (P&W) engine cycles as well as the airframe under development by Convair. The North American B-70 program was curtailed from 12 to 4 prototype Mach 3 aircraft, with an expected saving of $138 million in fiscal year 1962 and $1.4 billion by 1967.

• Despite these cuts, however, the Pentagon is asking almost $2 billion more for fiscal year 1962 now than it did in the January budget. Its appropriation request now totals $43.8 billion, with fiscal year 1962 spending reckoned at the same level.

• Additional funds were requested for almost every military space system under development. The list includes $60 million to speed development of the Midas infrared early warning system, $15 million for the Army's Advent communications satellite, $30 million more for the Dynasoar rocket-boosted glider, $30 million for more Discoverer shots, $14 million for Saint, $15 million for ARPA's Defender anti-ICBM research program, an increase of $50 million for the Skybolt air-launched ballistic missile, and $132.4 million for other programs, including the Samos reconnaissance satellite.

• Basic construction of the Army's $75 million Nike-Zeus complex at Kwajalein is substantially complete, and the installation of electronic equipment is well underway. The latter comprises four separate radar systems including the most powerful in the world (Zeus acquisition radar), three separate data-processing systems, and four concrete cells to house the 47-ft, 11-ton Zeus missiles. Tests will commence next year, first against small two-stage Speedball rockets fired to 200-mi altitude from Roi-Namur 45 mi to the north, and later against Atlas ICBMs fired 4400 mi across the Pacific from Vandenberg AFB.

• Nike Zeus' toughest test will come in 1963: Intercepting a warhead in a complete decoy environment. For this it will need its discrimination radar and associated computer system to measure the deceleration rates of the individual reentering objects and thereby to pick the heavy warhead from the lighter decoys. Construction of the discrimination radar has only just begun, and the Army will perform its initial intercepts without its services. No nuclear or chemical explosives will be used in the tests; miss-distance gear in the Zeus warheads will permit a determination of whether they are fast and accurate enough to catch their fleeting targets in nuclear fireballs before they penetrate deeply into the atmosphere.

ORGANIZATION

• The USAF Air Research and Development Command has been subjected to another sweeping reorganization, in which it absorbs a substantial portion of the Air materiel Command and becomes the Air Force Systems Command (AFSC). The new command has total responsibility for the development, test, and production of new USAF hardware systems through installation and checkout. AFSC will consist of four principal divisions: Ballistic Systems Div. and Space Systems Div. in Los Angeles, Aeronautical Systems Div. in Dayton, Ohio, and Electronic Systems Div. in Bedford, Mass. The new command will have 165,000 people and will absorb about 30% of AMC's annual budget.

SPACE AND PATENTS

• Patent policy, the nub of a powerful underlying conflict in the conduct of space, defense, and other public programs, receives the attention of 17 leading experts in the current issue of the Federal Bar Journal. The tenor of opposing views on patent policy and its effects appears in these excerpts from papers by Senator Russell B. Long and Representative Overton Brooks, both of Louisiana.

• Arguing against the state holding patents, Representative Brooks comments:

"What happens when we require by law (as we now do) that inventions made under research contracts of NASA and of other Government agencies on behalf of NASA become the property of the United States? Several things happen, none constructive.

"For one thing, the American space effort suffers because contractors (a) do not put forth their best efforts, or (b) they increase the cost of their research services, or (c) they refuse to take on the work which the Government needs. As one of many examples, note the fact that American manufacturers best qualified to produce badly needed gravity instruments for our lunar flight program have flatly declined to contract with NASA because of its patent policies . . . Net result: Our space effort suffers; so does our standing in the world community; so does our national defense.

"Secondly, the American patent system itself is undermined to the extent that our space effort affects patents . . ."

• Senator Long takes this position:

"If our Nation desires to attain the objectives of growth, efficiency, free competitive enterprise and social justice . . . the Government must stop giving away to private firms patent monopolies resulting from Government-financed inventions . . .

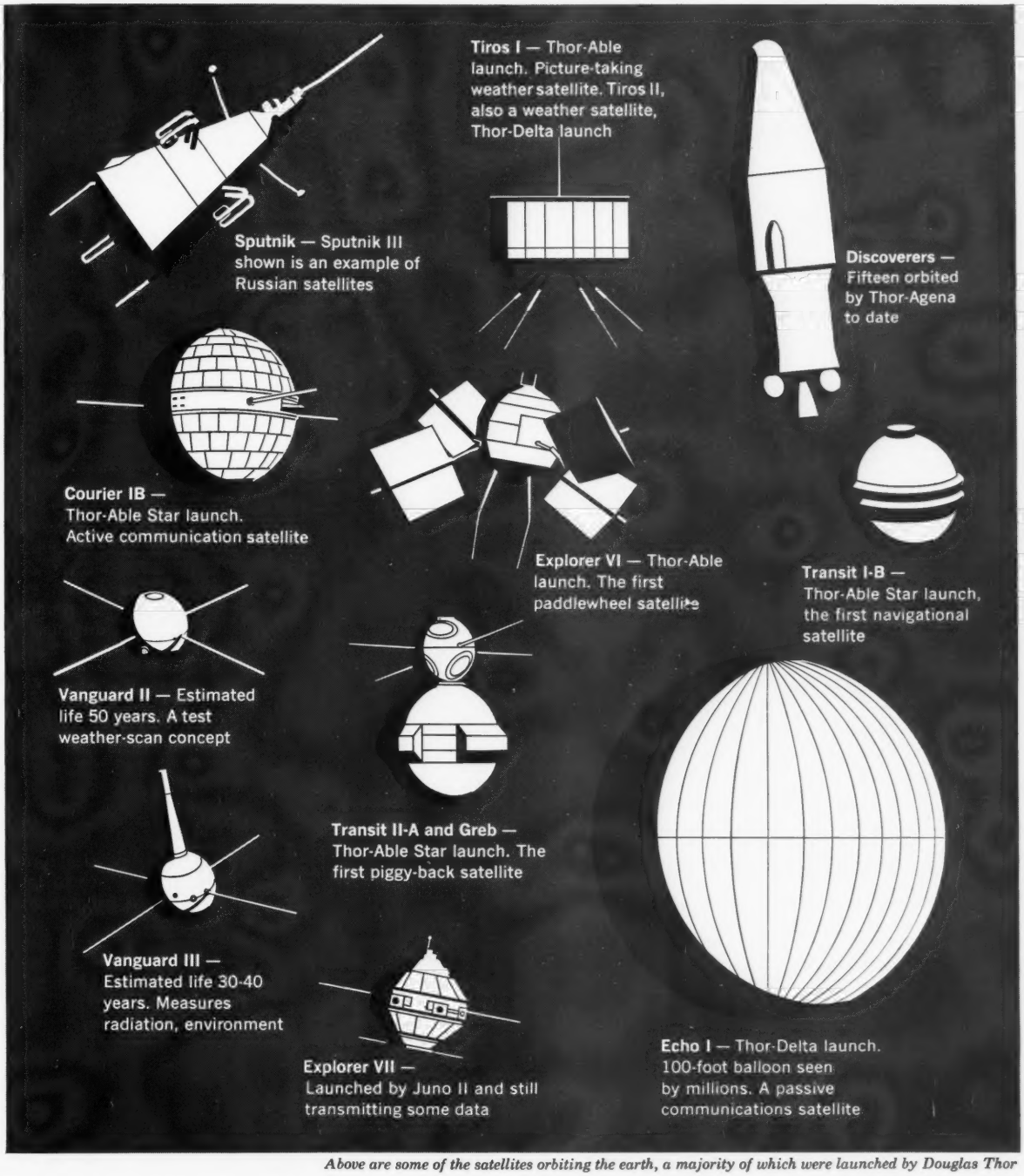
"The present policies of the Department of Defense are serious impediments to the creation and dissemination of new knowledge. These policies are retarding the rate of our scientific advance and undermining the very security of our country . . .

"The policies of the Department of Defense, the National Science Foundation, the Post Office Department, and the Treasury Department, in giving away to private companies patent rights to inventions developed at Government expense, coupled with the fact that 95% of the Government R&D funds go to the largest companies, tends to promote monopoly . . ."

Among agencies retaining patents, Senator Long cites the Atomic Energy Commission, the Department of Health, Education and Welfare, the Department of Agriculture, and the Federal Aviation Agency.

VON KARMAN HONORED ON 80TH BIRTHDAY

• This month in Washington, on the occasion of his 80th birthday, May 11, Theodore von Karman will be honored by some 1500 prominent members of the technical community attending a symposium and banquet in his name. The Air Force Office of Scientific Research and the IAS will sponsor and manage this commemoration of Dr. von Karman's many achievements in the building of flight science. ♦♦


Tiros I — Thor-Able launch. Picture-taking weather satellite. Tiros II, also a weather satellite, Thor-Delta launch
Sputnik — Sputnik III shown is an example of Russian satellites
Discoverers — Fifteen orbited by Thor-Agena to date
Courier IB — Thor-Able Star launch. Active communication satellite
Explorer VI — Thor-Able launch. The first paddlewheel satellite
Transit I-B — Thor-Able Star launch, the first navigational satellite
Vanguard II — Estimated life 50 years. A test weather-scan concept
Transit II-A and Greb — Thor-Able Star launch. The first piggy-back satellite
Vanguard III — Estimated life 30-40 years. Measures radiation, environment
Explorer VII — Launched by Juno II and still transmitting some data
Echo I — Thor-Delta launch. 100-foot balloon seen by millions. A passive communications satellite

Above are some of the satellites orbiting the earth, a majority of which were launched by Douglas Thor

The Douglas Thor rocket has orbited more satellites than all other rockets combined!

Of all satellites put in orbit since 1958, 55% were launched by the Air Force-NASA Thor IRBM. In its last 83 tactical and space firings by the Air Force, Navy and NASA, 86% have been completely successful—a reliability inherited from forty years of Douglas experience in aviation and 21 years in missiles and space.

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For the Record

The month's news in review

March 3—AF successfully launches four-stage Blue Scout II rocket with 172-lb payload to 1580-mi altitude.

March 7—X-15, piloted by Maj. Robert M. White, sets world speed mark of 2650 mph.

March 8—DOD directive gives lion's share of military space development projects to Air Force.

March 9—Soviet Union orbits and returns 5-ton satellite carrying a dog named Chernushka.

—Harold Brown, director of Univ. of California's Lawrence Radiation Laboratory, is appointed director of research and engineering for the Dept. of Defense.

March 10—NASA awards study contracts for rocket boosters of 6 to 12 million lb thrust to Convair, Lockheed, and North American Aviation.

March 16—NASA reports JPL Goldstone tracking station bounced radar signals off Venus and back to earth.

—NASA dedicates Goddard Space Flight Center at Greenbelt, Md.

March 18—Mercury test capsule overshoots target, comes down 20 mi out at sea instead of planned 6 mi.

March 21—Edward C. Welsh appointed chief officer of the National Aeronautics and Space Council.

March 22—NAS Geophysics Research Board gives preliminary plans for an International Year of the Quiet Sun (IQSY) during 1964-65.

March 24—Redstone launches Mercury capsule 115 mi into space in successful proof test.

—Atlas-E is fired in attempt to hurl dummy warhead 9000 mi over Atlantic.

March 25—Explorer X is launched into "yo-yo" (wide swinging) earth orbit, encounters unexpectedly strong magnetic fields 60,000 to 112,500 mi from earth.

—Soviet Union orbits another 5-ton space vehicle, carrying dog named Zvezdochka, and successfully returns it to earth.

March 27—AT&T chooses Andover, Me., as the site for the company's satellite-communications tests.

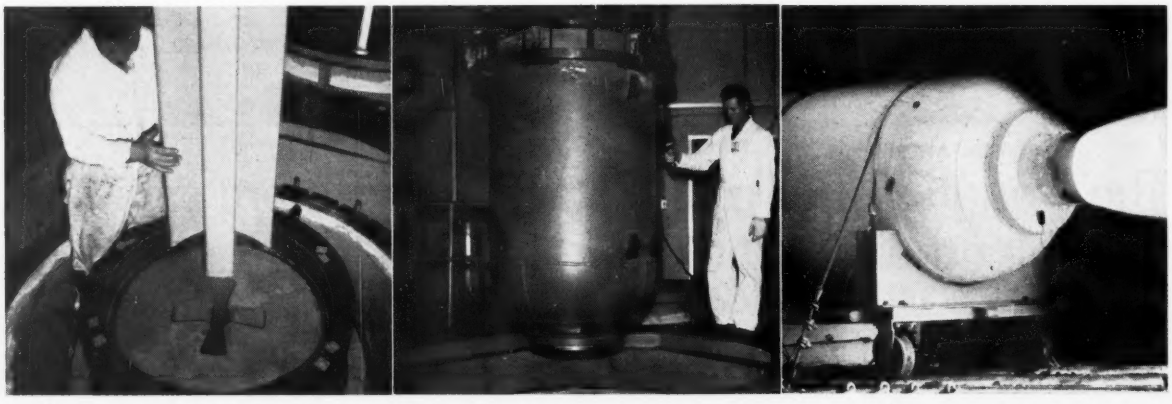
March 28—President Kennedy asks Congress for $125.7 million increase in NASA's space budget in effort to accelerate booster capacity, calls for increased buildup of Polaris subs and Minuteman ICBM bases, but proposes cutback in B-70 program and dropping of nuclear-plane project.

March 30—AF fails in attempt to orbit Discoverer XXII with new precision guidance system.

—X-15, piloted by Joseph A. Walker, climbs to world altitude record of 169,600 ft.

Rocketdyne Shows Some Solid Operations

Rocketdyne's Solid Propulsion Operations, McGregor, Tex., recently successfully static-fired a 38-in.-diam casebonded solid-propellant motor at an initial temperature of −75 F, after cycling it twice between −75 and 170 F. The big experimental motor employed 3500 lb of Rocketdyne's Flexadyne propellant, which is based on an advanced polybutadiene binder. Company officials say Flexadyne has relatively high specific impulse, high density, and superior physical properties, particularly resistance to tearing or cracking at low temperatures, thus qualifying it for use in solid rockets of the million-pound-thrust class and propulsion units for such applications as air-launched missiles which must qualify for a wide range of operational temperatures.



Photos show, from left, the motor in the casting pit after die removal, the motor being withdrawn from the pit, and static firing at an initial temperature of −70 F. Note the smooth appearance of the grain perforation in the photo showing die removed.

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Each production unit is thoroughly tested and additional operating and destructive testing is accomplished on selected units.

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On the calendar

1961

May 3–5	**ARS/ORNL Space-Nuclear Conference, Oak Ridge National Lab, Gatlinburg, Tenn.**
May 8–10	IRE National Aerospace Electronics Conference, Biltmore & Miami Hotels, Dayton, Ohio.
May 8–12	"Spectrum of Space Medicine, Annal IV of Space Exploration" and selected topics on space medicine during Annual Convention of N.Y. State Medical Society, War Memorial Auditorium & Hotel Manger, Rochester, N.Y.
May 9–11	Western Joint Computer Conference, Ambassador Hotel, Los Angeles, Calif.
May 22–24	**ARS National Telemetering Conference, Sheraton Towers Hotel, Chicago, Ill.**
May 22–24	National Symposium on Global Communications, co-sponsored by AIEE and IRE, Hotel Sherman, Chicago, Ill.
June 13–16	**National IAS-ARS Joint Meeting, Ambassador Hotel, Los Angeles.**
June 19–21	Heat Transfer and Fluid Mechanics Institute Conference, Univ. of Southern California, Los Angeles.
June 19–21	**International Academy of Astronautics on Earth Satellites and Re-entry Trajectories, Paris.**
June 19–23	Fifth Biennial Conference on Carbon, Pennsylvania State Univ., University Park, Pa.
June 23–24	Franco-Italian Colloquium on Sounding Rockets, Paris
June 26–28	First European Symposium on Space Technology, London.
June 26–30	"Concepts and Design in Aero-Space Electricity" is theme of 1961 Aero-Space Transportation Committee (AIEE), Benjamin Franklin Hotel, Phladelphia, Pa.
July 9–14	4th International Conference on Bio-Medical Electronics and 14th Conference on Electronic Techniques in Medicine and Biology, Waldorf-Astoria Hotel, New York, N.Y.
Aug. 1–3	4th Western Regional Meeting of American Astronautical Society, Sheraton-Palace Hotel, San Francisco, Calif.
Aug. 7–9	**ARS Guidance and Control Conference, Stanford Univ., Palo Alto, Calif.**
Aug. 14–22	Modern Developments in Heat Transfer special summer course, Univ. of Minnesota, Duluth, Minn.
Aug. 16–18	**ARS International Hypersonics Conference, MIT, Cambridge, Mass.**
Aug. 23–25	**ARS Biennial Gas Dynamics Symposium, Northwestern Univ., Evanston, Ill.**
Aug. 28–Sept. 1	International Symposium on Rockets and Astronautics sponsored by Japanese Rocket Society, Tokyo.
Aug. 28–Sept. 1	International Heat Transfer Conference, Univ. of Colorado, Boulder, Colo.
Oct. 2–4	Seventh National Communications Symposium of IRE Professional Group on Communications Systems, Municipal Auditorium and Hotel Utica, Utca, N.Y.
Oct. 2–7	**XIIth International Astronautical Congress, Washington, D.C.**
Oct. 4–6	American Society of Photogrammetry Semi-Annual Convention, Biltmore Hotel, New York, N.Y.
Oct. 9–15	**ARS SPACE FLIGHT REPORT TO THE NATION, New York Coliseum, New York, N.Y.**

PROJECT NERV

From the first Nuclear Emulsion Recovery Vehicle (NERV) launch and recovery on September 19, 1960, came these important accomplishments:

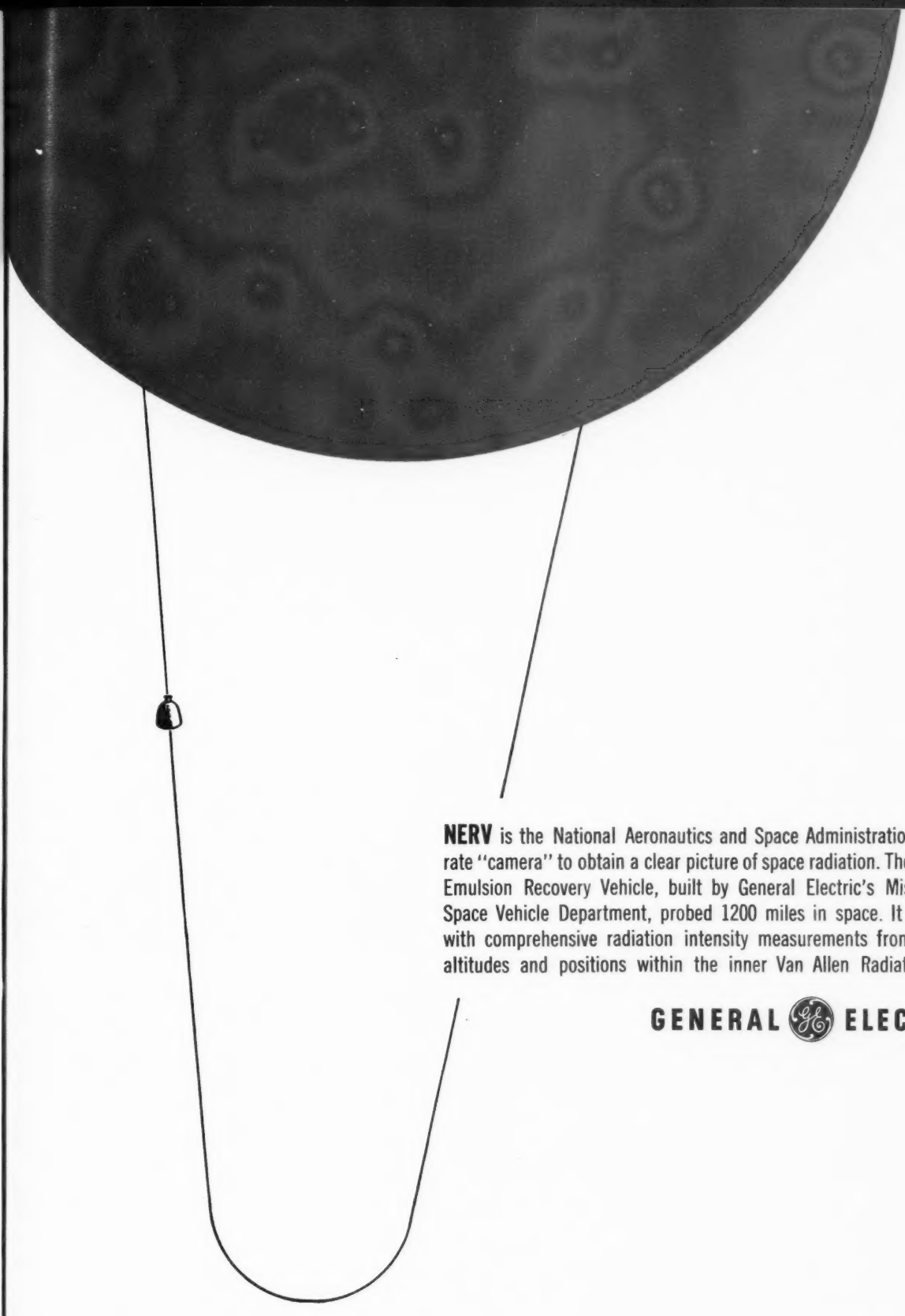
Highest Space Probe of a Recovered Vehicle—The 83.6 lb NERV (19″ wide and 17″ long) was recovered after a 1200 mile-high flight into the inner Van Allen Radiation Belt.

Detailed Measurements of Space Radiation A disc, 1/2″ thick and 3″ wide, extended from the vehicle during flight, exposing a stack of 25 layers of special emulsion to the radiation particles. Recovery permitted scientists to analyze the emulsion directly.

First Re-entry of a Vehicle with a Discontinuous Surface—The NERV ablation nose cone, intentionally discontinuous to permit exposure of the payload, was the first "broken" surface to survive the intense heat of re-entry. Performance of the vehicle was successful in all respects.

General Electric's Missile and Space Vehicle Department designed and built NERV for National Aeronautics and Space Administration's Goddard Space Flight Center. MSVD is a department of the G.E. Defense Electronics Division. 160-04

GENERAL ELECTRIC



NERV is the National Aeronautics and Space Administration's accurate "camera" to obtain a clear picture of space radiation. The Nuclear Emulsion Recovery Vehicle, built by General Electric's Missile and Space Vehicle Department, probed 1200 miles in space. It returned with comprehensive radiation intensity measurements from various altitudes and positions within the inner Van Allen Radiation Belt.

GENERAL ELECTRIC

MISSILE AND SPACE VEHICLE DEPARTMENT, PHILADELPHIA, PA.

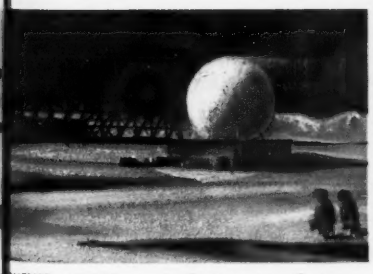
CREATIVE ELECTRONICS BY RCA

"WEATHER EYE" IN SPACE

RCA-NASA Development of TIROS Advances Progress in Worldwide Weather Forecasti

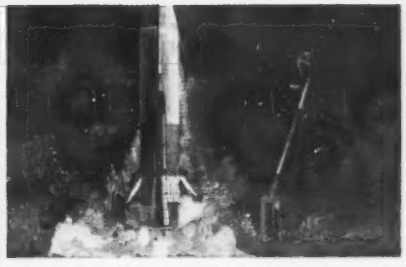
From its vantage point in space, TIROS is sending down to earth new, more definite pictures and data of the world's everchanging weather patterns to aid man in his ageless efforts to control the elements.

Incorporating revolutionary and advanced electronic equipment, TIROS was designed, developed and built by RCA's Astro-Electronics Division for National Aeronautics and Space Administration. Within its small circumference are miniature TV cameras, tape recorders, TV transmitters, command r ceivers, timing mechanisms, beacons and telem equipment. In addition, it carries new scanning a non-scanning Infra-red Sensing Devices, developed NASA, to measure and record the heat radiation the earth and its cloud cover, and a revolutionary m Magnetic Orientation Device to capitalize on t effects of the earth's magnetic field and maint favorable orientation of the satellite for long perio



MEWS—RCA Electronics Equipment and Systems contribute to the alert status of the Nation's ast outer perimeter early warning system.

DAMP—at the Caribbean down-range missile testing "slot," the highly complex DAMP vessel is equipped with RCA electronic tracking devices.



ATLAS—an RCA-developed checkout and launch system reduces substantially the "countdown" period required for launching this missile.

CA developments in miniaturization, reliability, computing and overall elec-nic activities are contributing to many of the nation's leading space and missile ojects. For information describing new RCA scientific developments, write Dept. 4, **Defense Electronic Products,** Radio Corporation of America, Camden, N.J.

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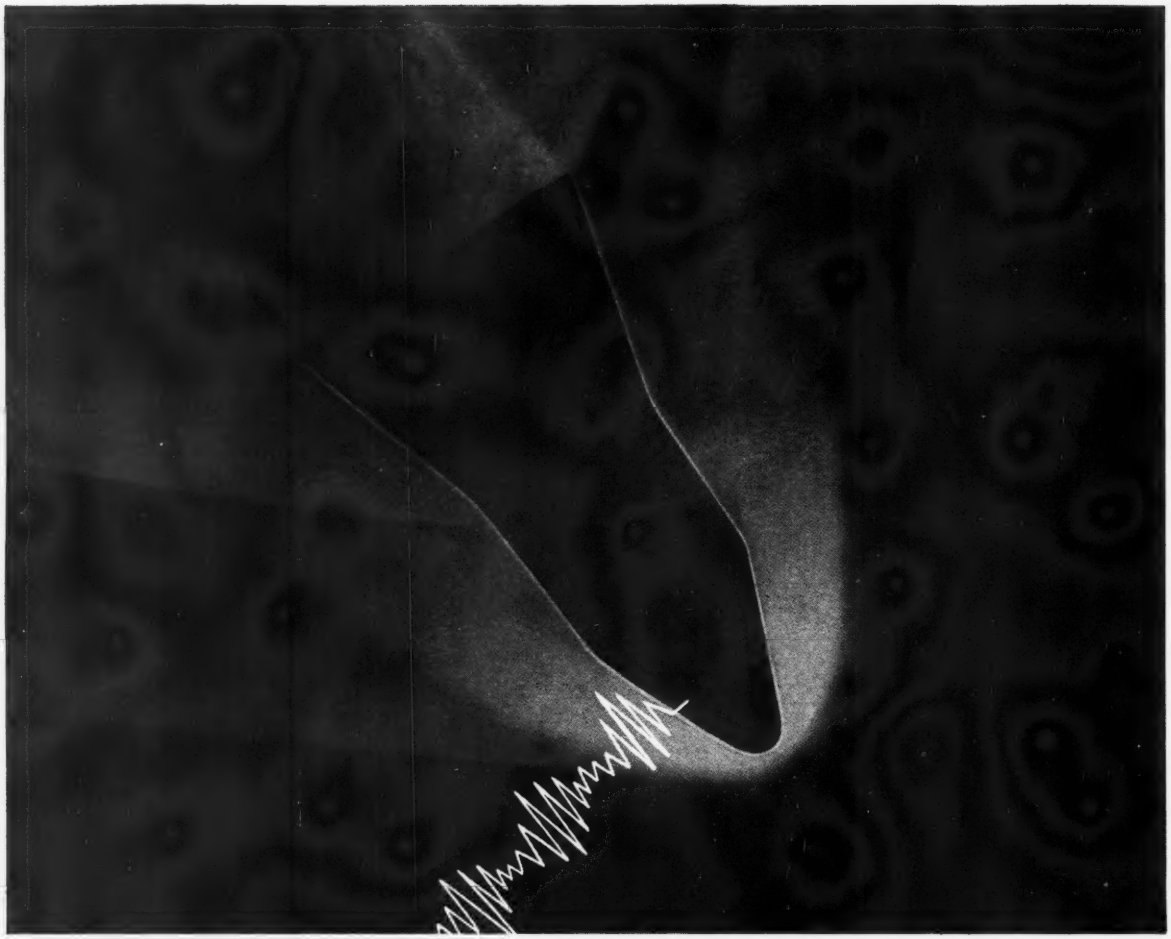

Piercing the plasma sheath...

When ICBMs, satellites or space probes re-enter the earth's atmosphere, frictional heating is so intense that air surrounding the vehicle becomes a "plasma sheath." This acts as a barrier to conventional radio telemetry. AVCO/RAD has developed a Direct Re-entry Telemetry (DRET) system for the U. S. Air Force. The DRET system has been flown on Atlas and Titan ICBMs and has successfully transmitted signals to airborne monitoring equipment. Engineers and scientists at AVCO/RAD are also working on techniques for continuous communications with re-entering manned vehicles, as well as on other conditions in which a plasma barrier exists and where signal penetration is required.

Airborne re-entry tracking team of Avco's RAD Division monitor an Avco Mark 4 re-entry vehicle launched by Titan ICBM.

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Not Enough GOOD Meetings

It is rather commonplace to hear the question: "Do professional people spend too much time in meetings?" One wag even suggested that it would be an improvement to spend the first 11 months of the year in meetings and then take December off to get some work done.

Certainly, the total meetings held in any important realm of technology will add up to an excessive number. Much of the blame is placed on the professional societies, but actually other agencies contribute to a greater degree—among these are Government organizations and laboratories, universities, corporations, and, in some cases, small groups of individuals. Agreed, there is some overlapping and duplication of effort among the professional societies. However, it is the policy of ARS to minimize duplication by effective scheduling of meetings, arranging joint general meetings, combining specialty conferences, and holding meetings at adjacent geographical locations.

Further, ARS is very desirous of merging with societies whose spheres of interest are almost 100% overlapping. Over the past few years, ARS has made numerous overtures to AAS for merger and has been very liberal in making concessions to make the merger attractive to AAS members. That these offers were declined is disappointing, but it is not the privilege of ARS to pass judgment.

Returning to the question of the number of meetings and the agencies responsible for them, the number contributed by all organizations, including military-support organizations, military agencies, universities, and corporations would run into the hundreds. For example, one segment of a military organization has scheduled, in conjunction with various other groups, 21 meetings in the field of space technology during a $7^1/_2$-month period of 1961. In addition, there are numerous symposia and honorary dinners sponsored by small groups and even by individuals.

The ARS contributes exactly 12 meetings to the grand total. These consist of 10 specialist conferences limited to those people interested in the particular specialty, one general annual meeting in October, and one semi-annual meeting in June. ARS exerts all possible effort to hold these conferences jointly with other societies; for example, the semi-annual meeting is being held jointly with IAS.

The problem is not just too many meetings, but rather not enough *good* ones. Therefore, in the final analysis, the solution to the problem is direct and simple: Attend the ones that are worthy of your presence and stay away from the others. The AMERICAN ROCKET SOCIETY, through the efforts of its members and technical committees, must assure that its meetings are important, meaningful, and worthy of the efforts of the attendees. The growth of membership, the general and continuous improvement in content in technical sessions and publications, and the general increase in esteem within the scientific community would indicate that the Society is performing its role in at least an acceptable manner.

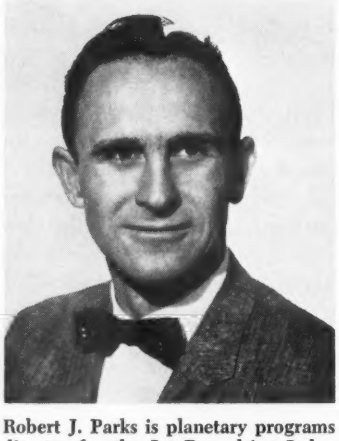
Harold W. Ritchey
President, AMERICAN ROCKET SOCIETY

The U.S. planetary exploration program

The goal—a comprehensive knowledge of translunar and interplanetary space by 1970—will necessitate developing new families of instruments, better thermal-control systems, and more reliable spacecraft

By Robert J. Parks

NASA JET PROPULSION LABORATORY, PASADENA, CALIF.



Robert J. Parks is planetary programs director for the Jet Propulsion Laboratory, responsible for NASA-JPL's unmanned missions to the planets and interplanetary space. After receiving a B.S. in electrical engineering from CalTech in 1944, he served with the Army Signal Corps for 2½ yr, eight months with U.S. Occupation Forces in Germany. He was associated briefly with Hughes Aircraft as a radio engineer, and then joined JPL in 1947. He was JPL's program director for the Army's Sergeant field ballistic missile, described by military experts as "America's first truly 'second generation' surface-to-surface tactical missile," as well as chief of the JPL group for research and development of missile guidance systems, communications, and tracking.

THE UNITED STATES is planning the exploration of the near planets and interplanetary space in the decade 1960–70, using presently available launching vehicles and other, more-advanced systems due to reach the firing pad later in this decade.

As the cognizant U.S. agency for nonmilitary space operations, NASA has assigned to the Jet Propulsion Laboratory of California Institute of Technology the responsibility for both the lunar and planetary unmanned exploration programs. Centaur and Saturn launching vehicles have been allocated for use in the planetary programs and will be furnished by Marshall Space Flight Center.

Preliminary design of the first U.S. spacecraft was concluded in late 1960, and the detail design, engineering, hardware fabrication, and test stages are in process for early planetary and interplanetary missions. Other follow-on projects are in the preliminary study phase.

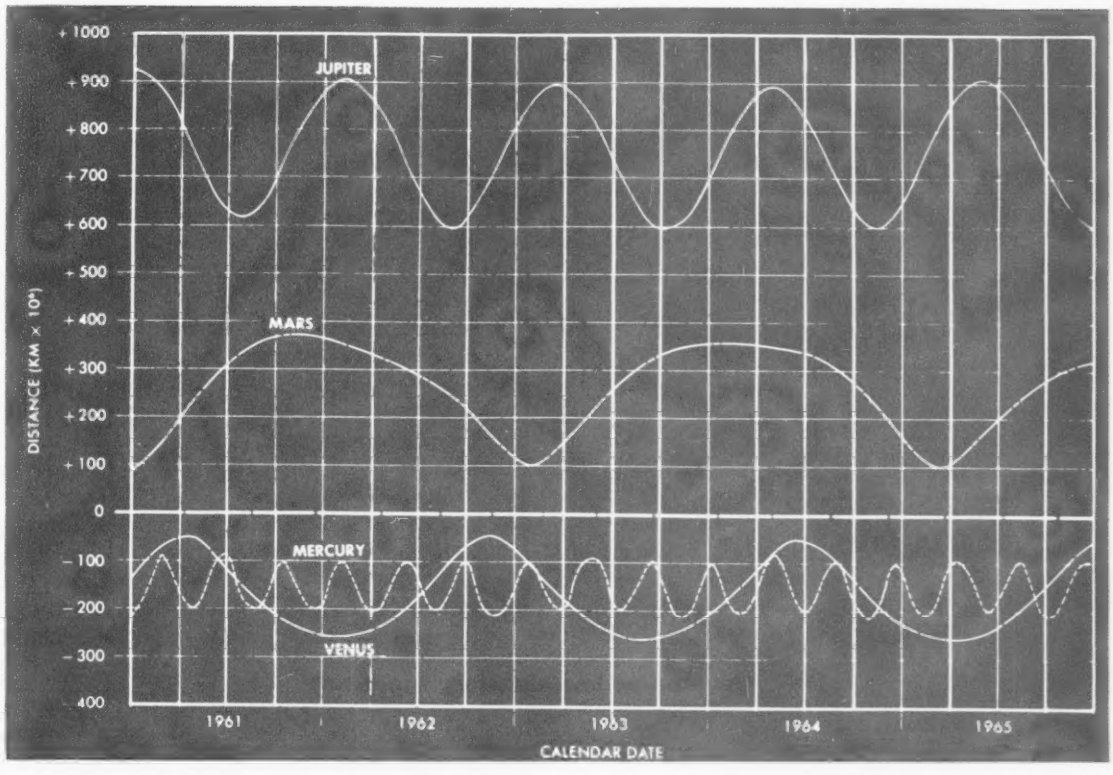
Program Objectives

The primary long-range objective of our planetary and interplanetary programs is the development of automatic, unmanned spacecraft technology and its application in spaceprobes to gather fundamental scientific knowledge concerning the planetary environments, the planets themselves, and solar phenomena, both within and out of the plane of the ecliptic (earth's orbital plane).

The secondary long-range objectives of the program are the development of technology and the collection of scientific data which will contribute to the eventual manned exploration of the planets and interplanetary space.

By 1970, the goal is to have demonstrated and exploited, in terms of acquired scientific data, spacecraft capable of orbiting Mars and Venus and of landing on the surfaces of these planets. Futhermore, it is planned by 1970 to initiate programs for probing the planets Mercury and Jupiter and for penetrating interplanetary space out of the plane of the ecliptic.

Relative Distances and Periods of Planets



Scientific Goals

The broad scientific objectives of the program relate to answering the following two questions:

Is extraterrestrial life present on the near planets?

What can be learned of the origin and evolution of the solar system and its multitude of component bodies?

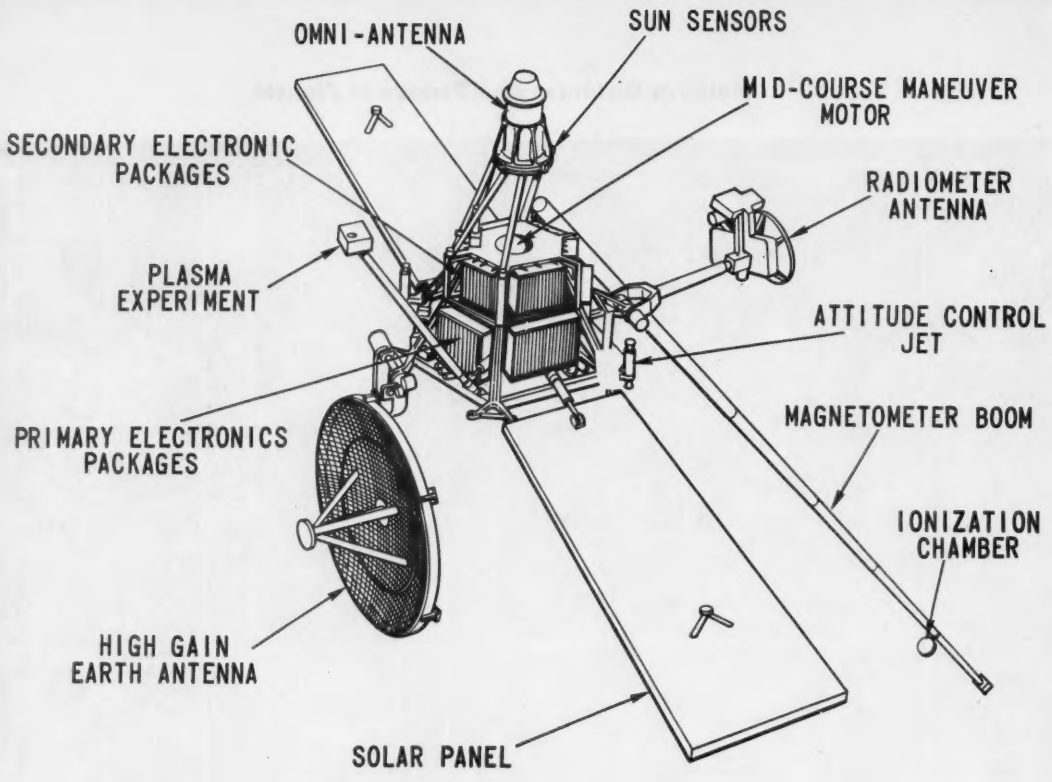
The discovery of life on another planet would be one of the most momentous events in human history. More than answering a universal curiosity, such a discovery would also be of enormous scientific interest. Next to the synthesis of living matter in the laboratory, it would be the one most important steps toward an understanding of the origin of life.

Much must be accomplished in the investigation of the physical nature of the planets. Little is known about Venus other than its mass and trajectory. It has an atmosphere that is visually opaque, but the reason for this opaqueness is not known. Its atmosphere is known to contain at least 500 times the amount of carbon dioxide as the atmosphere of earth. There is a small amount of water vapor above the reflecting layer but the total water content is still unknown. The surface and atmospheric temperatures, the atmospheric constituents, the rotation rate, and the spin axis are typical items of fundamental importance that must be determined.

The changing character of its surface is the central question concerning Mars. The simplest explanation relates this phenomenon to some life process, which must have some interaction with the planet's atmosphere. Thus, some of the most important information that the first Mars missions can obtain concerns its atmospheric constituents and the possible existence of organic molecules on its surface.

Many of these basic measurements of the general characteristics of the planets' surfaces and atmospheres are not only of direct and immediate scientific value, but are required for the design of the entry and landing spacecraft that will be launched by the Saturn vehicle. These spacecraft will be necessary for the detailed and unambiguous measurement of the phenomena of the planets. Even the magnetic-field and particle-measurement experiments proposed for the first Venus missions have relevance in the design of future communication systems.

In other words, early priority must be given to measurements which are required to design the follow-on spacecraft.



The Mariner Interplanetary Spacecraft

Restraints

Program plans have been influenced by such restraints as planet availability, launch-vehicle availability and capability, and spacecraft technology.

The chart on page 23 shows in a general way the proximity of the planets to earth and the periods of launch availability. Launch opportunities will consist roughly of a 1- to 2-hr period each day for approximately 1 month in each period of planet availability.

When the launching of a satellite or a lunar mission slips a month, a simple 1-month delay is introduced into the program. Significantly, in the case of a planetary mission, a 1-month slip usually will mean that another favorable launch opportunity will not be available *for a year or more*. Reliability thus assumes paramount importance at the launch complex and in flight.

The high order of complexity of planetary and interplanetary spacecraft is evidenced by the following typical restraints:

Communications. The spacecraft must be able to communicate engineering and scientific data (both in interplanetary space and in the vicinity of the target planet) to earth over extreme distances. Because of such distances, the transmitting equipment must utilize a directional antenna oriented toward earth. Two-way communications are necessary for precision tracking to determine orbits, to receive telemetry, and to transmit commands to the spacecraft in flight.

Guidance and Control. The spacecraft must approach closely enough to the target planet to make meaningful observations. This restraint requires adequate flight-path guidance as well as midcourse and perhaps terminal propulsion systems.

Directional Measurements. In order to make observations upon the target planet, the spacecraft must be able to detect the planet and properly align its scientific instruments.

Attitude Control. The spacecraft must be stabilized in space and controlled in attitude in order to execute proper orbit-correction maneuvers, to point

DSIF Station Locations

Station Location	Latitude	Longitude
Goldstone	35.389 deg N	116.848 deg W
Woomera	31.417 deg S	136.867 deg E
South Africa	25.891 deg S	27.675 deg E

solar panels toward the sun, to orient a directional antenna toward earth, and to align instruments with the planet. The sun will be used as one reference and either the earth or a star will be the reference for the third, or roll, axis.

Program Plans

The planetary program is divided into projects, dependent upon mission, spacecraft design, launch vehicle, and budget considerations. Venus and Mars missions utilizing the Centaur launch vehicle form the Mariner series. The first planetary mission employing Saturn will begin the Voyager series.

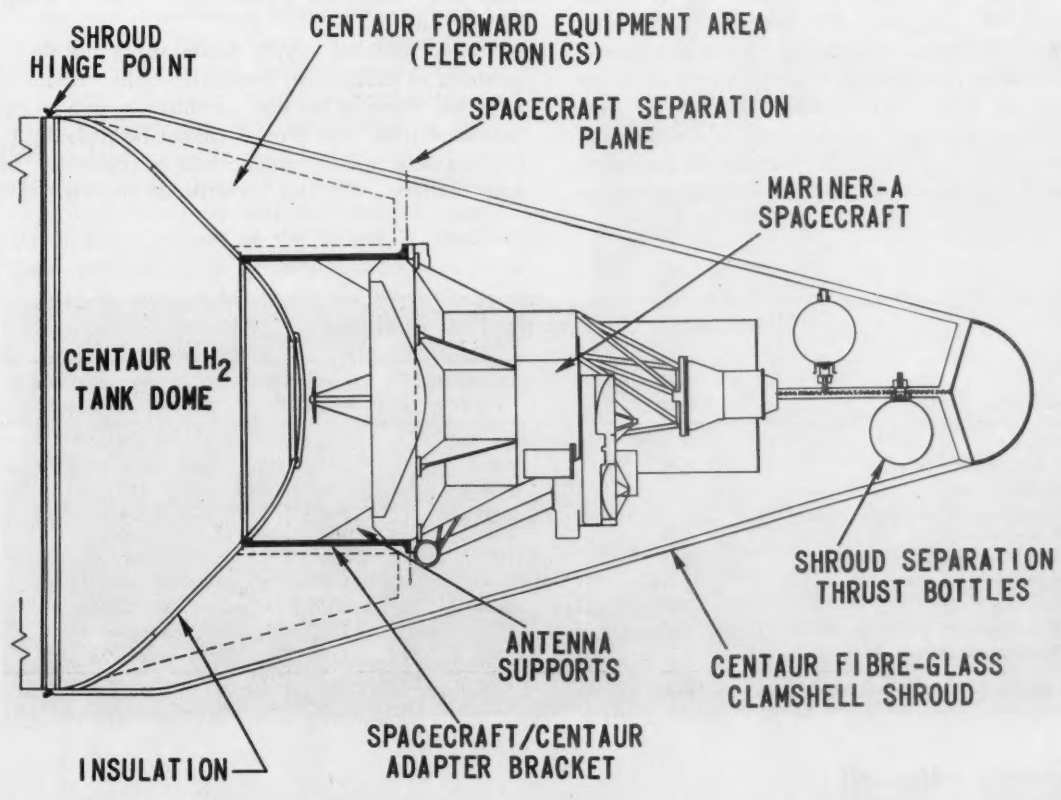
A major objective of the program involves successful Mars and Venus missions in 1964. To ensure reasonable confidence in these missions, spacecraft developmental flights are planned, starting in 1962.

An example of the type of developmental flights planned is an actual planetary flyby mission to approach within a nominal value of approximately 27,000 meters of the center of Venus in 1962, with a transit time in excess of 3 months. Another example would be the launch of a deep-space probe on a planetary-like trajectory outside the periods of Venus or Mars availability. Such a flight would provide flight-test experience with most of the spacecraft equipment and (CONTINUED ON PAGE 52)

Venus and Mars Mission Opportunities

1960 —		MARS
1961 —	VENUS	
1962 —	VENUS	MARS
1963 —		
1964 —	VENUS	MARS
1965 —	VENUS	
1966 —		MARS
1967 —	VENUS	
1968 —		MARS
1969 —	VENUS	
1970 —	VENUS	

Mounting of Mariner in Centaur Nose Cone



Part 2—Design Considerations

Deep-space communications

At the bargaining counter of the possible and practical are weighed factors of power conversion, transmission frequency, system particulars, and tracking requirements

By Eberhardt Rechtin

NASA JET PROPULSION LABORATORY, PASADENA, CALIF.

THE SEVERE weight penalty in space vehicles demands the use of highly efficient transmitters. Besides coding aspects, there is the problem of converting primary power, available in such forms as sunlight, chemical bonds, and nuclear energy, into an appropriate signal $s(t)$. Each of these primary power sources has different characteristics and therefore different applications.

The conversion of sunlight into signal energy by solar batteries, heat engines, or the equivalent will supply power (watts) for the lifetime of the equipment. The conversion equipment has weight. With solar batteries now available, a weight factor of 2 w/kg can be achieved, according to H. K. Ziegler of the U.S. Army Signal Engineering Laboratories. However, the lifetime of the equipment is limited by micrometeorites and X-rays to 10 yr or less. In addition, of course, the available sunlight power per unit area depends on the distance to the sun. (At 10^8 km approximately 3.5 kw/m^2 is received from the sun, less than 10% of which is typically converted to electricity.) The power per unit area decreases as the square of the distance from the sun. Hence, this source of power will decrease as a space vehicle goes in the direction of Mars and will increase in the direction of Venus.

Batteries Limit Operations

Chemical batteries supply a total amount of energy (watt-hours). Chemical batteries (mercury cells) now available can supply about 100 whr/kg, although in this case surge loads are limited. For high surge loads, the weight factor is more nearly 20 whr/kg.

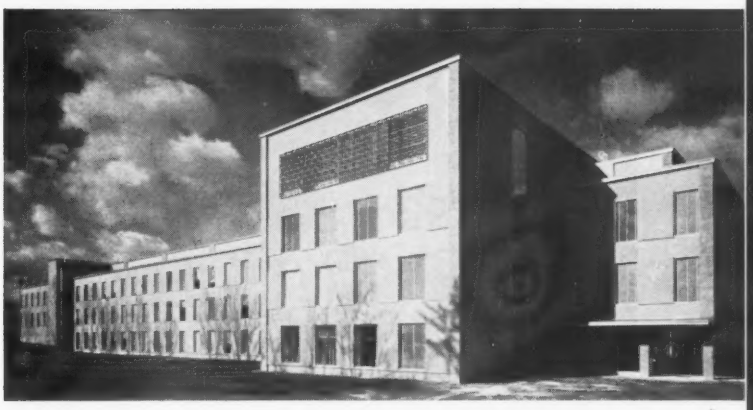
Atomic batteries supply power using the decay products of radioactive material. Unlike chemical batteries, there is no way of drawing power out "ahead of time"; the process cannot be rushed. In this characteristic the atomic battery resembles the solar battery. On the (CONTINUED ON PAGE 82)

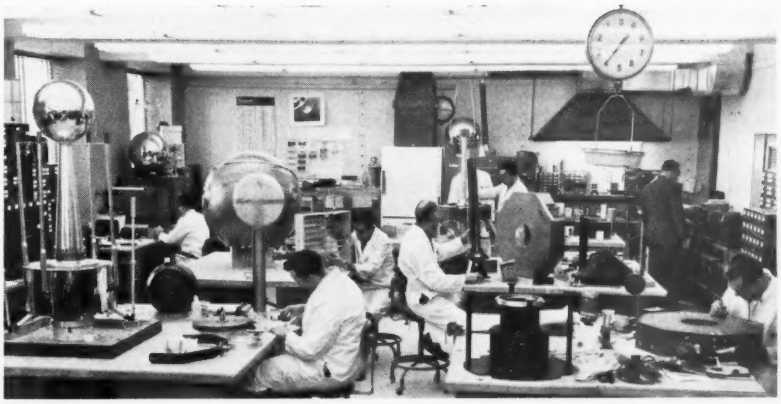
Illustrative Communication Systems

Parameter	Lunar orbiter with TV	Lunar lander with TV	Mars orbiter with TV	Cosmic-ray probe at edge of solar system
Range, km	4×10^5	4×10^5	4×10^8	4×10^{10}
Ground antenna gain	$4 \times 10^{4*}$	10^8	10^8	10^8
Vehicle antenna area, m^2	7	2.5	100	100
Vehicle antenna beamwidth, deg	2.2*	3.6*	0.6*	0.6*
System temp, K	220	400	100	100
Vehicle radiated power, watts	50	10	150	150
Frequency region, kmc	1–10	1–10	1–10	1–10
	(2.3)	(2.3)	(2.3)	(2.3)
Video bandwidth for $P_r/N = 10^3$ cps	10^6	10^6	2.5×10^9	too small
Video bandwidth for $P_r/N = 10$	10^3	10^3	2.5×10^5	25

* Geometric constraint; note: $\Delta\theta = 46\lambda/\sqrt{A} = 164/\sqrt{G}$.

NASA's Goddard Space Flight Center dedicated



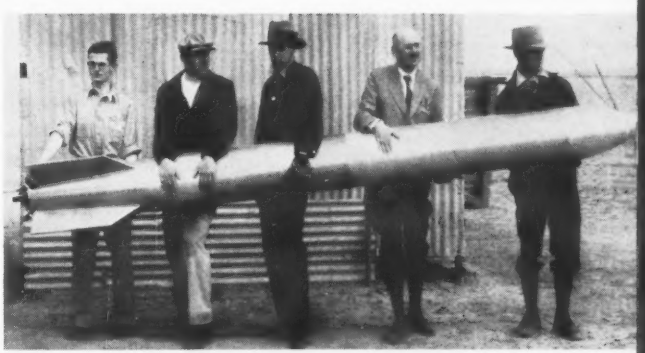


Top, Goddard's Research Projects Laboratory, one of 8 buildings that will form the Center; left, space practitioners in the new satellite and sounding-rocket assembly area at the Center; and below, pioneers, including namesake Robert H. Goddard, second from right, with his rocket flown April 19, 1932.

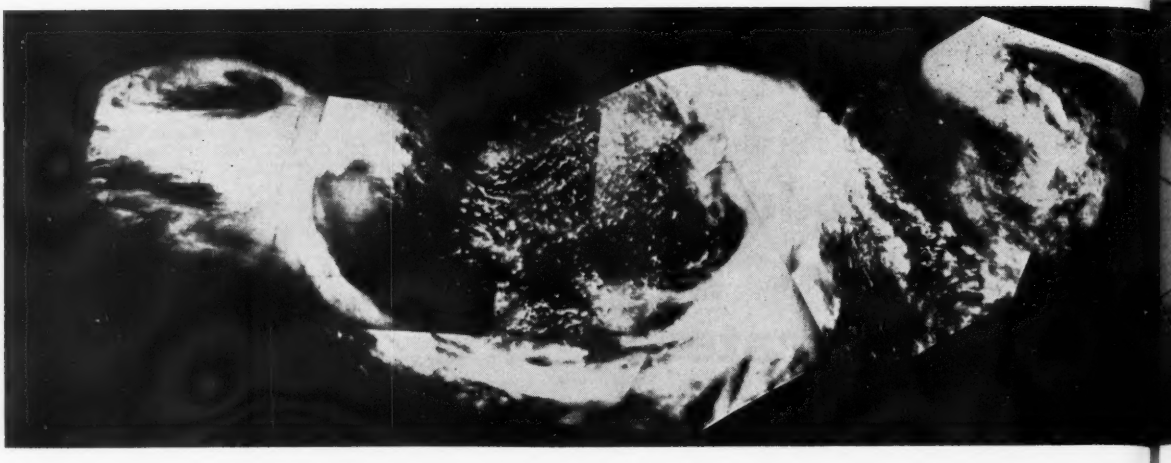
ROBERT H. GODDARD became more of his time with the formal dedication March 19th of the NASA Goddard Space Flight Center in Greenbelt, Md., the first completely new government scientific center created since the National Aeronautics and Space Administration was established on Oct. 1, 1958, and the nation's newest major facility devoted exclusively to the peaceful exploration of space.

The dedication ceremonies included the presentation to Mrs. Goddard of the Robert H. Goddard Medal, authorized by the 86th Congress on Sept. 16, 1959, in honor of her husband's life work. The presentation of the Medal to Mrs. Goddard was made jointly by Robert S. Kerr and Overton Brooks, chairmen, respectively, of the Senate and House space committees.

Harry J. Goett, first director of Goddard SFC, opened the ceremonies, and James E. Webb, NASA administrator, welcomed a distinguished audience. President of the National Academy of Sciences Detlev W. Bronk, introduced by NASA Deputy Hugh Dryden, made a moving dedication address. Mrs. Goddard, aided by Abe Silverstein, NASA director of space flight programs, unveiled a commemorative bust of Dr. Goddard. And an institution with a high goal, deserving its namesake, moved formally into the U.S. space program.

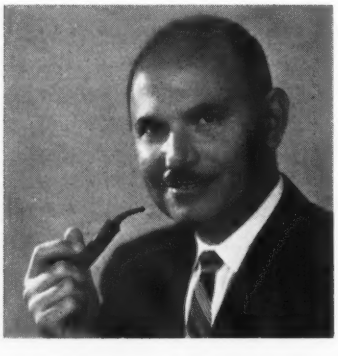


Actually, as attested, for instance, by Tiros, Echo, and Explorer X, Goddard SFC is already deeply involved in the space program. It will send aloft more than 100 sounding rockets and probes through calendar year 1962, and through 1963, 16 scientific satellites, 11 application satellites (7 weather and 4 communications), and two probes to distances greater than 4000 mi from earth. The experiments carried by these vehicles will increase our knowledge of the space environment, the earth itself, atmospheres and ionospheres, magnetic and electric fields, radiations, auroras, cosmic rays, the sun, other stars, nebulae, and per- (CONTINUED ON PAGE 50)



Tiros program results

Two history-making Tiros shots showed that satellite data can be extracted and transmitted to weather stations fast enough to profit forecasting and warrant advanced systems



By Morris Tepper

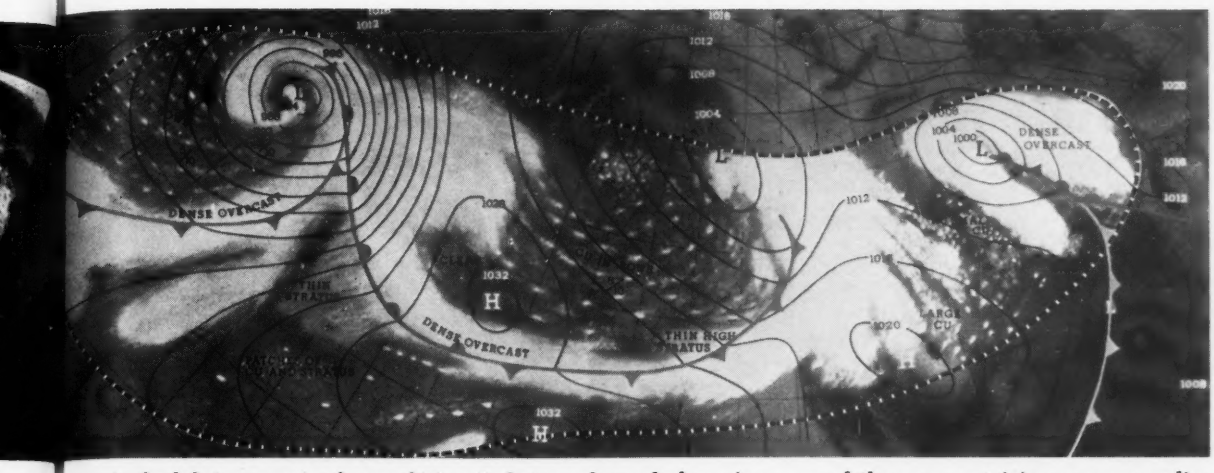
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, WASHINGTON, D.C.

Morris Tepper is chief of the Meteorological Satellite Program at NASA and chairman of its joint meteorological satellite advisory committee, as well as a member of other key panels and advisory groups in this field. A member of the staff of the U.S. Weather Bureau previously, since 1946, he was chief of its Severe Local Storms Research Unit when he joined NASA in 1959. In 1950, the American Meteorological Society gave him the Meissinger Award (jointly with John C. Freeman Jr.), and in 1952 Johns Hopkins Univ. conferred his Ph.D. in fluid mechanics. Besides his important contributions to the Tiros program, Dr. Tepper is known for proposing a theory on squall-line formation, based on the analogy to fluid flow in an open channel, and for his many papers on weather research.

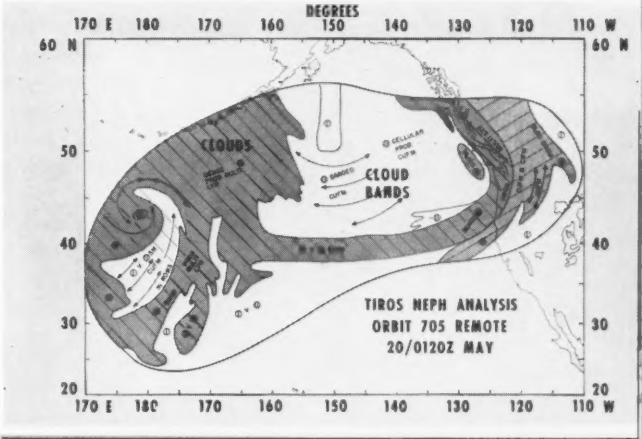
TIROS I was launched into orbit on April 1, 1960, and had a useful operating lifetime of 78 days. Tiros II was launched into orbit on Nov. 23, 1960, and at the time of this writing is still transmitting useful data. Without doubt, the year 1960 will go down in both space and meteorological history for introducing the world to these first two experimental meteorological satellites.

It is fitting, near the first anniversary of the Tiros I launch, to evaluate the results of the Tiros experiments and to interpret their immediate and future significance. I shall try to be brief and to concentrate on the more significant features.

Both Tiros satellites had essentially the same configuration. Tiros I weighed 270 lb, Tiros II 280 lb. Each was launched into a nearly circular orbit slightly in excess of 400 mi. They were both shaped like a hat box 19 in. high and 42 in. across. The top and sides were covered with solar cells, the primary source of power. The main sensors were two TV camera systems for photographing the earth's cloud cover. When viewing the earth vertically, one camera took pictures covering about 700 mi on a side, while the other took more detailed pictures, about 70 mi on a side. Tiros II, in addition, had nonscanning and scanning IR equipment to provide measurements of the atmospheric heat budget. The satellites were spin-stabilized, so the TV cameras and the nonscanning radiometers could view the earth only part of each orbit. Tape recorders stored pictures taken over areas distant from the U.S. and then read them out over the two command and data-acquisition stations.



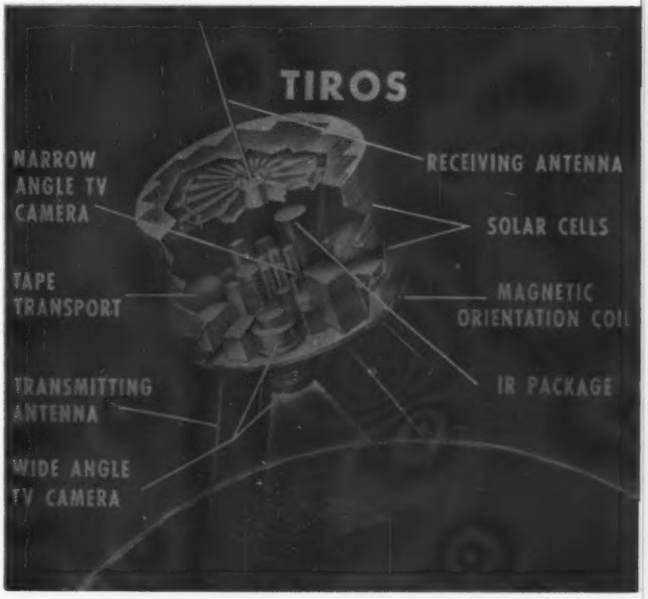
At the left is a mosaic of several Tiros I photographs, and above is a map of the area containing a corresponding meteorological frontal analysis. The clouds from the left figure have been drawn at the right in proper geographic location (after V. J. Oliver in the Oct. 1960 *Weatherwise*). Below is operational weather data—a nephanalysis—done on this mosaic. This analysis was transmitted in facsimile by the meteorological team at a data-acquisition station to the National Meteorological Center of the U.S. Weather Bureau at Suitland, Md. The cloudy areas are clearly depicted, as are the cloud bands themselves. The storm center south of the Aleutian Islands is outlined by the spiraling arrows.



Tiros was in effect a multiphased experiment. Over and above the more general problems and uncertainties underlying launch-vehicle development, launch operations, payload injection, and tracking—there were three basic questions which the Tiros experiments were designed to answer.

1. *Could a satellite system be developed around TV cameras and IR radiation detectors to transmit with satisfactory fidelity the measurements of these sensors to the earth?*

This question can be answered without hesitation with an unqualified YES. In the last analysis, the almost 23,000 pictures acquired by Tiros I and the similar number acquired by Tiros II to date, as well as the considerable volume of IR data, all provide the most convincing testimonial of successful satellite system operation. The brilliance of this performance is only slightly dulled by the fact that the wide-angle camera in Tiros II was somehow defocused during launch. The resulting pictures, although not of the same quality as those from Tiros I, still show clearly the larger cloud and land areas, and lack only detail.



Success by Interdependence

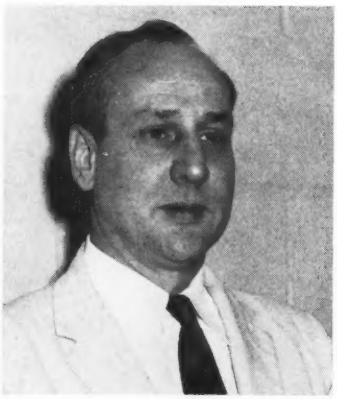
This remarkable performance required the successful operation of many interdependent and delicate subsystems, components, and electronics. Most of these are fully described in seven papers in the June 1960 issue of *Astronautics* and in a report on Tiros I to be issued shortly by Goddard Space Flight Center of NASA. In (CONTINUED ON PAGE 63)

Transit program results

Not only has the Transit system shown worldwide navigation by satellite to be practical, but it will also help reduce the chief impediments to its most precise use—weaknesses in geodesy

By Richard B. Kershner

APPLIED PHYSICS LABORATORY, JOHNS HOPKINS UNIV., SILVER SPRING, MD.



Richard B. Kershner is director of the Transit program at the Applied Physics Laboratory, where for a decade previously he was "Mr. Terrier" as supervisor of APL's Terrior Div. His career began at Johns Hopkins, where he received a Ph.D. in mathematics, and took him to the Univ. of Wisconsin and then back to his home university as a rising professor of mathematics. World War II saw him turn his attention to the pressing problems of interior ballistics and then the design of recoil-less guns and rocket devices, first at the Carnegie Institution in Washington and then at APL. After the war, Dr. Kershner followed his growing interest in rocketry by joining the APL Launching Group, and worked on booster developments, exterior ballistics, and the guidance of the STV-3 test vehicle, out of which was to grow Terrier. His sustained interest in pure mathematics took the form of a book, co-authored with L. R. Wilcox, "The Anatomy of Mathematics," published in 1950 and now the basis for courses in a number of schools and colleges.

"TRANSIT" is the code name for a program to develop and establish a system of near-earth satellites that provide a means for determining position (navigating) anywhere on the surface of the earth. The development phase is being carried out for the Bureau of Naval Weapons primarily by the Applied Physics Laboratory of Johns Hopkins Univ., with cooperative efforts by the Naval Weapons Laboratory at Dahlgren, Va., the Naval Ordnance Test Station at China Lake, Calif., and the Pacific Missile Range. The launching of the satellites is conducted by the Air Force's Ballistic Missile Div.

As a navigation system, Transit will have the virtues of true global coverage, all-weather operation, relative immunity to interference (either natural or man-made), unlimited traffic handling, frequent availability of fixes (every 100 min or oftener), and very high accuracy. On the other hand, since position is available only intermittently, and not continuously, for some purposes Transit may not replace the various radio aids that do provide continuous position fixing in the areas where such aids are available. However, it should be noted that a relatively modest inertial system would suffice to provide continuous interpolation between Transit fixes.

The principle on which the design of the Transit system is based is quite simple: That a constant-frequency radio transmission from an earth satellite is received by a ground station at the surface of the earth with an apparent variation of frequency. This variation in received frequency, the result of the well-known doppler effect, is an accurate measure of the rate of change of the slant range between the transmitter and the receiver, and hence is influenced both by the motion of the satellite in inertial space and by the motion of the receiving station as a point on a rotating earth.

Owing to the constraints imposed on the path of an earth satellite by Newton's laws, and our reasonably complete knowledge of the forces acting, it is possible, simply from an accurate measurement of the doppler shift at a ground station during the passage of a satellite within line of sight, to do either of two things: (1) Determine the orbit of the satellite if the position of the ground station is known or (2) determine the location of the ground station if the orbit of the satellite is known.

These two calculations are the basis of the Transit system. The second calculation is performed by the navigator using a description of the orbit provided to him and a measurement of the doppler shift, which is made by his (navigating) equipment. The first calculation (or an elaboration of it) is used by the organization

Transit Results

LAUNCH DATE:	APRIL 13, 1960*	JUNE 21, 1960	FEB 21, 1961
FREQUENCIES "B" SYSTEM: (100 MW EACH): "C" SYSTEM:	162–216mc 54–324mc	162–216mc 54–324mc	162–216mc 54–324mc
RMS FREQUENCY NOISE AS MEASURED AT TRACKING STATIONS: "B" SYSTEM: 162–216mc "C" SYSTEM: 54–324mc	5 PARTS IN 10^9 5 PARTS IN 10^{10}	1 PART IN 10^9 7 PARTS IN 10^{10}	5 PARTS IN 10^{10} 5 PARTS IN 10^{10}
FREQUENCY STABILITY: (Changes with mean satellite temperature) "B" SYSTEM: 162–216mc "C" SYSTEM: 54–324mc	1 PART IN 10^9/HR 1 PART IN 10^9/HR	3 PARTS IN 10^9/HR 5 PARTS IN 10^{10}/HR	1 PART IN 10^{10}/HR 1 PART IN 10^9/HR
AREA/MASS RATIO:	5.98 x 10^{-3} cm^2/gm	8.12 x 10^{-2} cm^2/gm	3.0 x 10^{-3} cm^2/gm
INITIAL PERIGEE ALTITUDE:	378 km	621 km	178 km
INITIAL APOGEE ALTITUDE:	754 km	1070 km	978 km
INCLINATION:	51.3 deg.	66.7 deg.	28.4 deg.

* NOTE: Nav 1B ceased radiating on July 11, 1960.

operating the system to determine the orbits for distribution to those using the doppler measurements made at special ground stations at known locations. Of course, the second calculation is vastly simpler than the first, and can be done with much more accuracy, since only two variables (latitude and longitude) are required to specify the location of a ground station, while the specification of a satellite orbit requires that at least six parameters be determined.

Tracking Data Ample

Fortunately, the first calculation usually need not be done, since it is generally possible, for tracking the satellite, to acquire more information than the doppler data for a single pass at a single ground station. In fact, the tracking of Transit satellites is accomplished by the use of the doppler data measured at a multiplicity of ground stations and extending over a period of time (say, 12 hr) that includes a number of passes at each ground station. However, it is of interest technically that the multiplicity of doppler curves simply provides redundancy and a consequent increase in accuracy, and that each doppler curve, in principle, provides enough data to determine the orbit.

To complete a description of the operation of the Transit system, it is only necessary to add that the formidable communication problem of disseminating a description of the orbit to all potential users is solved by using the (CONTINUED ON PAGE 106)

NRL's Lofti communications-research satellite sits atop Transit 3-B during a preflight checkout. The Transit program both benefits from pickaback techniques and contributes to the growing pickaback technology.

Project Echo results

Its glittering sphere made apparent the promise of worldwide satellite communications, and delivered a wealth of data to development groups

By Leonard Jaffe

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, WASHINGTON, D.C.

Leonard Jaffe was appointed chief of the Communications Satellite Program in NASA's Office of the Assistant Director of Advanced Technology in January 1959. Previously, he was head of the Data Systems Branch at the NASA Lewis Research Center. Jaffe has specialized in research in electronic instrumentation, data and information transmission, and data processing by means of computers. After receiving a B.S. in electrical engineering from Ohio State Univ. in 1948, he joined the then NACA Lewis facility as an aeronautical research scientist. During his 11 yr at Lewis he worked on electronic instrumentation in its Physics Div., served as head of its Automatic Data Handling Section, and was head of its Data Systems Branch from 1956 to 1958.

THE SUCCESSFUL launching of the Echo I satellite on Aug. 12, 1960, culminated an effort which began at NASA's Langley Research Center in early 1959 to develop a 100 ft-diam spherical satellite which could be used as a communications reflector. The satellite development and qualification test program included many simulated environmental and flight tests.

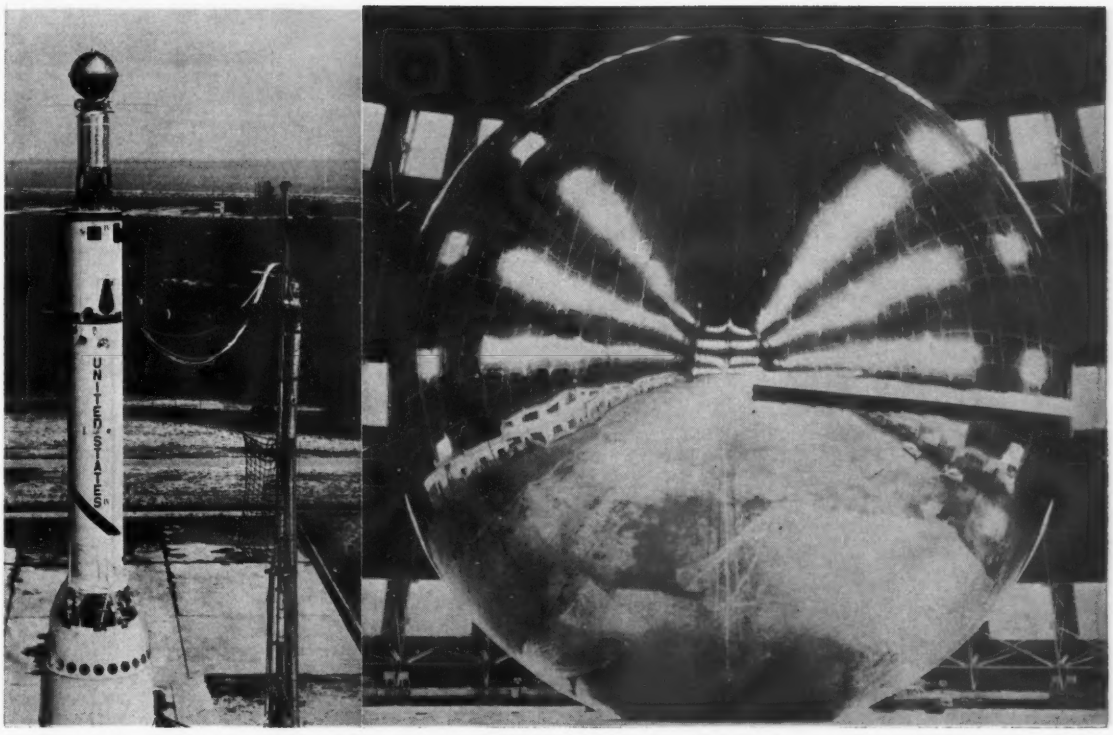
Echo I was made of Mylar 0.0005 in. thick coated with vapor-deposited aluminum to provide radiowave reflectivity. The 100-ft diam sphere weighed 136 lb and was folded into a 26-in.-diam container for launching. Two sublimating powders were sifted into the satellite (20 lb of anthraquinone and 10 lb of benzoic acid) to inflate it in the vacuum of space. Four inflation tests were made in 41-ft-diam vacuum chambers at the Langley Research Center, and five free-space environmental tests were made in ballistic flights with rockets from NASA's Wallops Island Test Station. These tests developed the packaging, ejection, and inflation techniques which resulted in the successful deployment of Echo I in orbit.

Beacons for Tracking

The final flight spacecraft carried two radio beacons operating at 108 mc/s to assist in tracking the satellite. These beacons, developed by RCA, weighed 11 oz, were powered by solar cells and batteries, and delivered approximately 10 mw of radio frequency power to an erectable dipole antenna.

Over-all Project Echo management responsibility was assigned to the Goddard Space Flight Center of NASA. In addition to the planning and execution of flight operations and communications experimentation, Goddard was responsible for integration of the Echo spacecraft with the Delta launch vehicle, developed by Douglas Aircraft.

Concurrently with the satellite and launch-vehicle development, communication facilities were being developed and constructed at the Jet Propulsion Laboratory facility at Goldstone, Calif., and Bell Telephone Laboratories at Holmdel, N.J.; and modifications were made to an existing NRL facility at Stump Neck, Md. The primary communications experiments were carried on from JPL to BTL at 2390 mc/s, and from BTL to JPL at 960 mc/s. NRL received and transmitted at 2390 mc/s.



In a brief few hours in orbit, the Echo I sphere dramatized without ambiguity the potential of worldwide satellite communications. From a 26-in.-diam canister, shown at the left mounted on the launching Thor-Delta vehicle in a preflight checkout, it inflated in space to the impressive 100-ft-diam balloon seen at the right in a development test at one of NASA-Langley's hangars.

The 85-ft parabolic antennas were used at JPL, one for receiving and one for transmitting. At BTL, a 60-ft parabolic antenna was used for transmitting and a newly developed 20- x 20-ft -aperture horn antenna was used as a receiver (see page 35). Both facilities employed 10-kw transmitters. Parametric-amplifier receivers were employed at JPL, and a liquid-helium-cooled maser was in the receiver at BTL.

Automatic antenna tracking techniques were developed at JPL, in addition to equipment which would position the antennas from prediction drive tapes, which were used at all sites. This equipment was exercised and proved out in numerous experiments, using the moon and the Tiros I satellite as targets. It was NASA-Goddard's responsibility for generating orbital predictions accurate enough for the pointing of the communications antennas.

In addition to the prime experimenters, NASA invited industry and academic institutions, both here and abroad, to participate in Project Echo by performing independent communications experiments using the satellite.

In brief this is the background to Project Echo. What have been the results from the only partially analyzed data?

In a very short time following Echo I launching, a number of significant communications experiments were performed. On the first orbit of the satellite (within 2 hr of the launch) a previously recorded message by President Eisenhower was transmitted from the West Coast to the East Coast of the United States via the satellite. This was particularly significant, because at that very time a solar disturbance caused interruption of high-frequency, long-distance communications. Following rapidly was the first two-way telephone conversation via a satellite and the transmission of a signal across the Atlantic Ocean to experimenters in France. On August 22, voice and music were successfully transmitted via Echo I from BTL in New Jersey to the Jodrell Bank radiotelescope in England.

On August 19, the Collins Radio Corp. in Cedar Rapids, Iowa, and their affiliate, the Alpha Corp. in Richardson, Tex., successfully transmitted the first facsimile picture via Echo.

On Nov. 10, 1961, NASA assisted the U.S. Post Office Dept. in an experiment to determine the use of satellites for the transmission of "Speed Mail." A letter was scanned, transmitted via Echo I, and reprinted at the receiver in approximately 5 min. It is estimated that future (CONTINUED ON PAGE 80)

Practical problems of satellite communication

To achieve a practical system soon, we must weigh world conditions, unknowns of space, and other factors against the resources of a sophisticated electronics art

By John R. Pierce

BELL TELEPHONE LABORATORIES, MURRAY HILL, N.J.

John R. Pierce is director of Research, Communication Principles, for the Bell Telephone Laboratories. Dr. Pierce joined Bell Labs soon after receiving a Ph.D. in 1936 from the California Institute of Technology. From 1936 to 1955 he worked on high-frequency electron tubes, particularly traveling-wave tubes. He became director of electronics research in 1952, in 1955 became director of Research, Electrical Communications, and in 1958 assumed his present position, which includes research in radio, electronics, acoustics, vision, mathematics, and group behavior. The Bell Labs work on Project Echo originated in his department.

In 1948, Dr. Pierce received the IRE Fellow Award for his "many contributions to the theory and design of vacuum tubes." He is also the recipient of the Eta Kappa Nu (outstanding young electrical engineer) award for 1942, the IRE Morris Liebmann Memorial Prize for 1947, and the Stuart Ballantine Medal for 1960.

Besides many research and interpretive papers, Dr. Pierce has authored the books, "The Theory and Design of Electron Beams," "Traveling-Wave Tubes," "Electrons," "Waves and Messages," and "Man's World of Sound."

A GREAT deal of thought has been devoted to communication satellites since Arthur C. Clarke first proposed them in 1945 ("Extraterrestrial Relays" in *Wireless World*). Now, a good deal of work has been done as well, including Score, Echo, Courier, and pertinent noncommunication satellite launchings. At present we know enough to realize that the problems of satellite communications cannot be settled in a brief article. Here I propose merely to raise some important practical problems and comment on them.

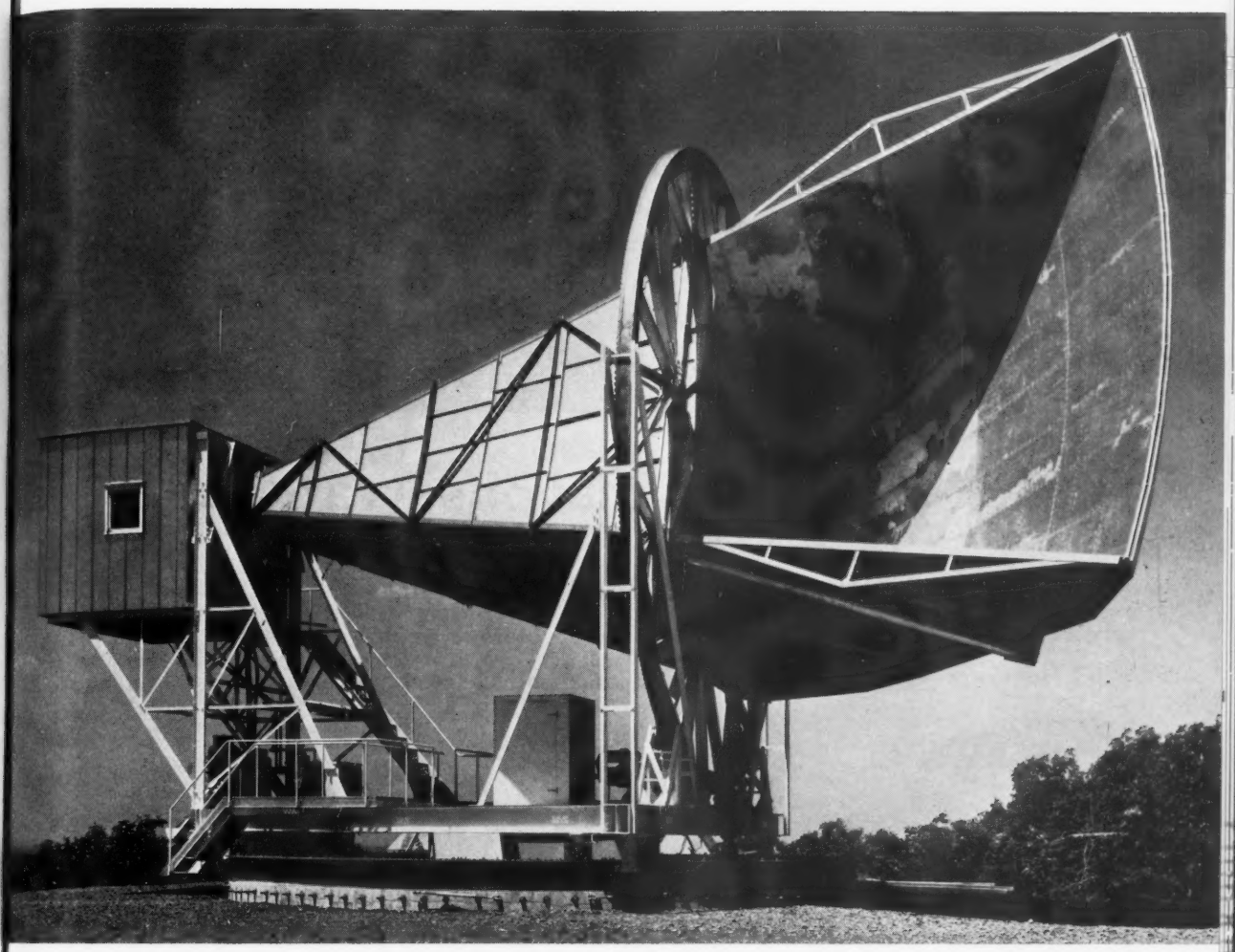
As preface, let me say that I believe that practical satellite communications can be achieved without any new ideas or "breakthroughs" (whatever they may be). In fact, several sorts of satellite communication systems could be made. To make any one sort work satisfactorily would take a great deal of time, money, research, and development. To choose sensibly among various kinds of systems, one must think of such broad matters as how quickly can a useful system be put into operation, how satisfactory will its performance be, and will it be economical.

A first and vitally important problem is how satellite communication can be fitted into our already highly developed communication systems, so as to expand their usefulness. While a satellite communication system might conceivably serve some individual and self-sufficient purpose, such a narrow and restricted use would seem a poor basis for what will necessarily be a very expensive undertaking.

There are about 134,000,000 telephones in the world. Particularly in Europe, North America, and Japan, these are interconnected by complicated, versatile, and adequate transmission and switching facilities. Together with these, the telephone operating companies or agencies provide facilities for the transmission of teletypewriter data, facsimile, and television signals.

Transoceanic Communications Inadequate

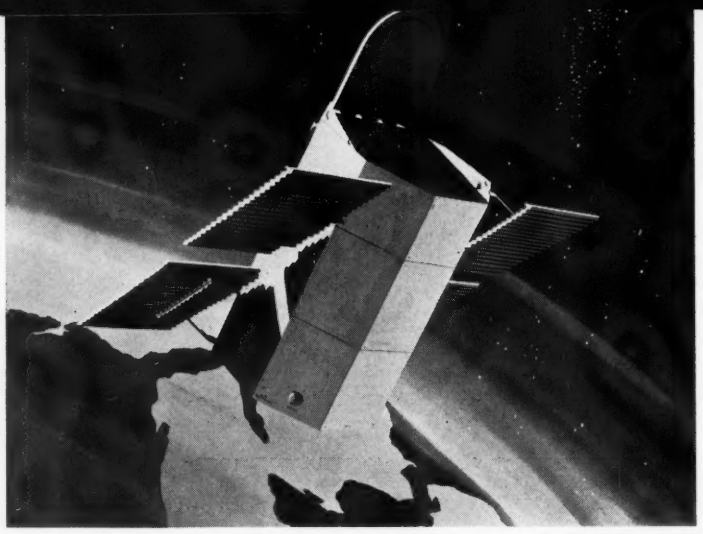
Transoceanic telephone traffic is growing rapidly. While there are a number of transoceanic telephone cables, and more will be built, the total number of transoceanic telephone circuits, cables, and radios is inadequate. We have no circuits of television bandwidth. It seems to me that the greatest, the most useful, the most economically attractive service that satellite communication could provide is that of linking together the large, highly developed communication systems of various continents.



A scarcely conceivable piece of equipment five years ago, this precision horn antenna at Bell Labs represents one reason there can be enthusiasm for an early practical satellite communications network. It employs a solid-state maser. The Project Echo receiving system embodying it gave an overall equivalent noise temperature of about 24 K (zenith). This figure is expected to be lowered to 15 K in the near future and to below 10 K ultimately. The Bell System's recently announced experimental satellite—communications ground station, being built near Rumford, Me., at a cost of about $7 million, includes five similar antennas, each 177 ft long and housed in a dome 210 ft across and 161 ft high.

What problems do we face in doing this? A pattern of international communication already exists. International operating standards must be compatible. Over a period of decades they have been worked out through the International Telecommunications Union, now a part of the United Nations. In each country the agency which provides telephone service owns and operates trans-Atlantic radio terminals. International telephone cables are owned jointly by the agencies of the countries they interconnect. Thus, the cable connecting the U.S. and Great Britain is owned jointly and equally by the British Post Office and the American Telephone and Telegraph Co.

It seems to me that the quickest, the surest, and perhaps the only way to achieve useful, mutually profitable satellite communication is within this established, functioning, nonpolitical international framework of cooperative technical standards, ownership and operation. It seems to me that any other approach would create a host of new and unnecessary problems without providing any substantial benefits. (CONTINUED ON PAGE 90)



NASA Orbiting Astronomical Observatory

Orbiting astronomical observatories

Astronomical data from these orbiting "Mt. Palomars," which involve most precise observational and operational equipment, will open a new era in stellar studies and cosmology

By Robert R. Ziemer

NASA GODDARD SPACE FLIGHT CENTER, GREENBELT, MD.

Robert R. Ziemer was assigned to his present position of Orbiting Astronomical Observatory project manager at NASA's Goddard Space Flight Center early in 1960. He graduated from Iowa State at Ames in 1944 and since that time has been engaged in various aspects of gas-turbine and rocket research at NACA and NASA. At the Lewis Research Center, he headed a section investigating the application of turbine cooling for increased gas-turbine performance. As a member of the Advance Engines Panel, he assisted in the design of a series of gas-turbine engines covering the range from subsonic transports to Mach 4.0 reconnaissance aircraft using a variety of special fuels. In 1957, as a member of the Space Vehicle and Systems Panel, he was engaged in initial research and design applicable to high-energy rocket test vehicles and a series of design studies of lunar-landing vehicles.

THE ADVENT of large earth satellites offers the astronomical community a new and exciting opportunity to explore those regions of the spectrum that are now inaccessible because of atmospheric absorption. The past restriction of observations to the small visible band between 3000 and 8000 Å, and the radio regions, has left the far-infrared and the wavelengths below 3000 Å unexplored. Now that observations in these bands are possible above the absorbing atmosphere of the earth, major scientific advances can be expected in the study of the planets, stars, nebulae, and interstellar matter. In addition to opening the spectrum for astronomical observations, the use of satellites will eliminate the astronomer's problem of differential refraction by the earth's atmosphere and, through the elimination of atmospheric scattering, will increase the resolution of the objects to be studied. Thus, the use of earth satellites offers unlimited possibilities for an increased understanding of the origin of the universe.

The NASA Orbiting Astronomical Observatory (OAO) is a precisely stabilized satellite designed for astronomical observation. Its concept embodies the ideas of eminent astronomers in several specialized fields and those of a number of NASA personnel. During early studies aimed at determining the most rewarding types of experiments, it became apparent that the requirements imposed on the observatory or spacecraft by many experiments are, in general, quite similar. In fact, with few exceptions a long-life system concept developed for one set of experimental equipment will satisfy

all others. Two such common requirements are the precision attitude-control system and ground programming, which are expected to be the major problems in the engineering development of the spacecraft. On the basis of these and many similar requirements, such as thermal control and a versatile command system, a basic spacecraft design was conceived and adopted.

Inherent in this approach are the following benefits:

(1) Amortization of the traditional high initial development cost of the spacecraft.

(2) Increased reliability and operating experience through repeated use.

(3) Maximum use of ground support and test equipment.

(4) Maximum use of special ground-station equipment and personnel.

Extend Observational Techniques

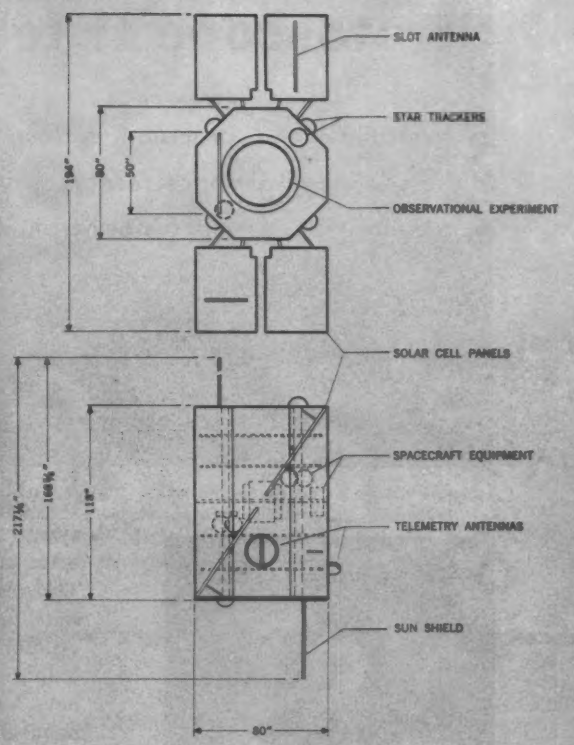
The major observing techniques planned for satellite astronomy are extensions of those developed for terrestrial observatories. However, the difficulties that attend the study of the lower and higher regions of the electromagnetic spectrum will necessitate unique new optical and detection systems, each tailored to a specific job. In addition, the problems of remote observations and operations must be solved, as well as problems of designing systems to withstand the rigors of the launching and then to operate successfully in the pressure and temperature environment of space.

The primary experiments for the first three observatory systems have been tentatively selected; they are all concerned with stellar astronomy in the ultraviolet range (1 to 3000 Å). The first OAO will carry two prime experiments of a complementary nature: (1) A mapping study of the celestial sphere in three ultraviolet ranges, under the direction of Fred Whipple of the Smithsonian Astrophysical Observatory, and (2) a broadband photometry study of individual stars and nebulae, which will be developed by the Univ. of Wisconsin team headed by Arthur Code. The following are the reasons for selecting these experiments for the first satellite:

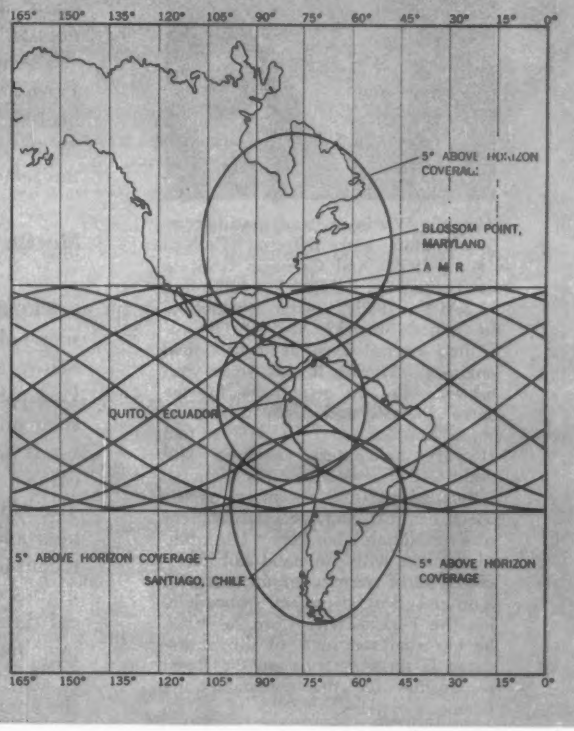
(1) Both sets of experimental equipment are intended primarily for survey work. The data will provide a comprehensive picture of the unknown field that lies ahead.

(2) There are always some risks inherent in the first flight of a new system. It is desirable, therefore, that the payload not be dependent upon maximum performance of the fine guidance and thermal-control systems. Moreover, with two complementary but in- (CONTINUED ON PAGE 58)

OAO General Layout



OAO Orbital Path at 500-mi Altitude


165° 150° 135° 120° 105° 90° 75° 60° 45° 30° 15° 0°
5° ABOVE HORIZON COVERAGE
BLOSSOM POINT, MARYLAND
QUITO, ECUADOR
5° ABOVE HORIZON COVERAGE
SANTIAGO, CHILE
5° ABOVE HORIZON COVERAGE

Stratoscope II telemetry and command

Its versatility and precision, reflecting the engineer's response to the challenge of space research, bulwark Stratoscope II's goal of making astronomical history from the fringe of space this year

By Alan B. Wissinger

PERKIN-ELMER CORP., NORWALK, CONN.

Alan B. Wissinger is a graduate of Washington and Jefferson College (B.A., 1952) and Carnegie Institute of Technology (B.S.M.E., 1952 and M.S.M.E., 1953). After graduation, he joined Sikorsky Aircraft Div. of United Aircraft Corp. as an analytical engineer. During his six years with Sikorsky, he was responsible for the servo analysis and flight testing of sonar couplers for the HSS-1 and HSS-1N helicopters, analysis and flight test of several stability augmentation devices and automatic engine speed controls, and the establishment of a simulation laboratory. His initial experiences with command and telemetry systems were in conjunction with a drone-helicopter project. Since joining the Perkin-Elmer Corp. in 1959, he has analyzed some of the Stratoscope II servo systems and has been responsible for the command and telemetry systems.

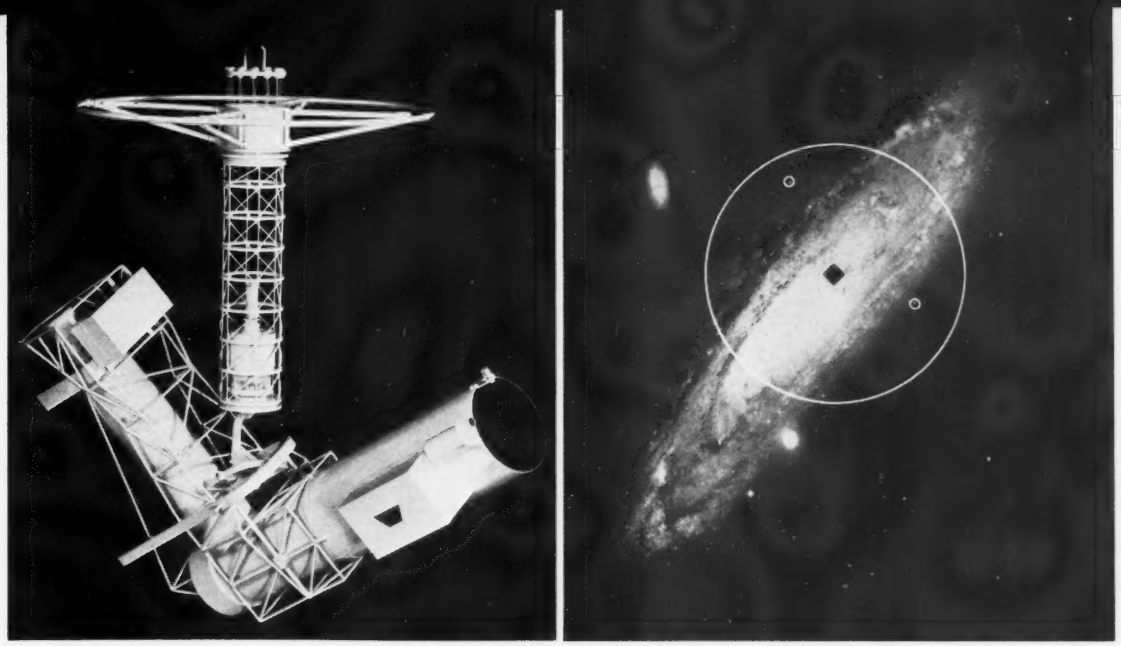
IN ORDER to get a really good look at the universe, it is necessary to lift a telescope above the atmosphere and operate it there. While it is fortunate for all of us that there is an atmosphere, it has always been a bane to astronomers. This is because the atmosphere, being unevenly heated, has greatly varying density, and is turbulent. This results in random refraction and distortion of the light from stars, making good observations difficult and high-resolution, long-exposure photography impossible. For example, the best photographs ever taken of night objects by any groundbased observatory have a resolution of $^1/_3$ of a second of arc, and the average astronomical photograph has a resolution of only 1 sec. One-third of a second of arc is the theoretical resolving power of a 12-in. mirror. This resolution just permits us, in exceptionally good pictures, to distinguish photographically objects which are 44 mi apart on Venus at its closest approach and 2 light years apart in the Andromeda nebula. In truth, man hasn't really seen much yet.

The refraction and distortion of the light rays, called "seeing" by astronomers, occurs close to the ground, where the air is unevenly heated, and in the tropopause, where the air is extremely turbulent. At an altitude of 80,000 ft, 96% of the atmosphere lies below, and the seeing is perpetually good.

Martin Schwarzschild's Experiment

The first successful attempt at utilizing a balloon to raise a telescope above the regions of poor seeing was made in 1957 by Martin Schwarzschild of Princeton Univ. Designed and manufactured by Perkin-Elmer, this telescope, utilizing a 12-in. mirror, was used for solar photography. This project, known as Stratoscope I, was sponsored primarily by the Office of Naval Research. In 1959, NSF became a co-sponsor, and early support was provided by the AFCRC. The sun was chosen as the initial object for research because its nearness and brightness permitted relatively unsophisticated guidance techniques. In six flights, the project yielded several hundred photographs of the sun with resolution closely approaching the theoretical diffraction limit. These results indicated that the problem of poor seeing can be solved through balloon astronomy.

The next step in improving our view of the heavens is to increase the aperture of the telescope, since the theoretical diffraction limit is



A scale model of Stratoscope II. The telescope is pointing up and to the right. The two large boxes on the sides of the telescope barrel house the command and telemetry equipment. Right, a photograph of the Andromeda nebula. The large circle represents the field of view of the telescope. The small black square at the center shows the area covered by the film, and the two small circles indicate the aperture of the tracking-servo image dividers.

inversely proportional to aperture.

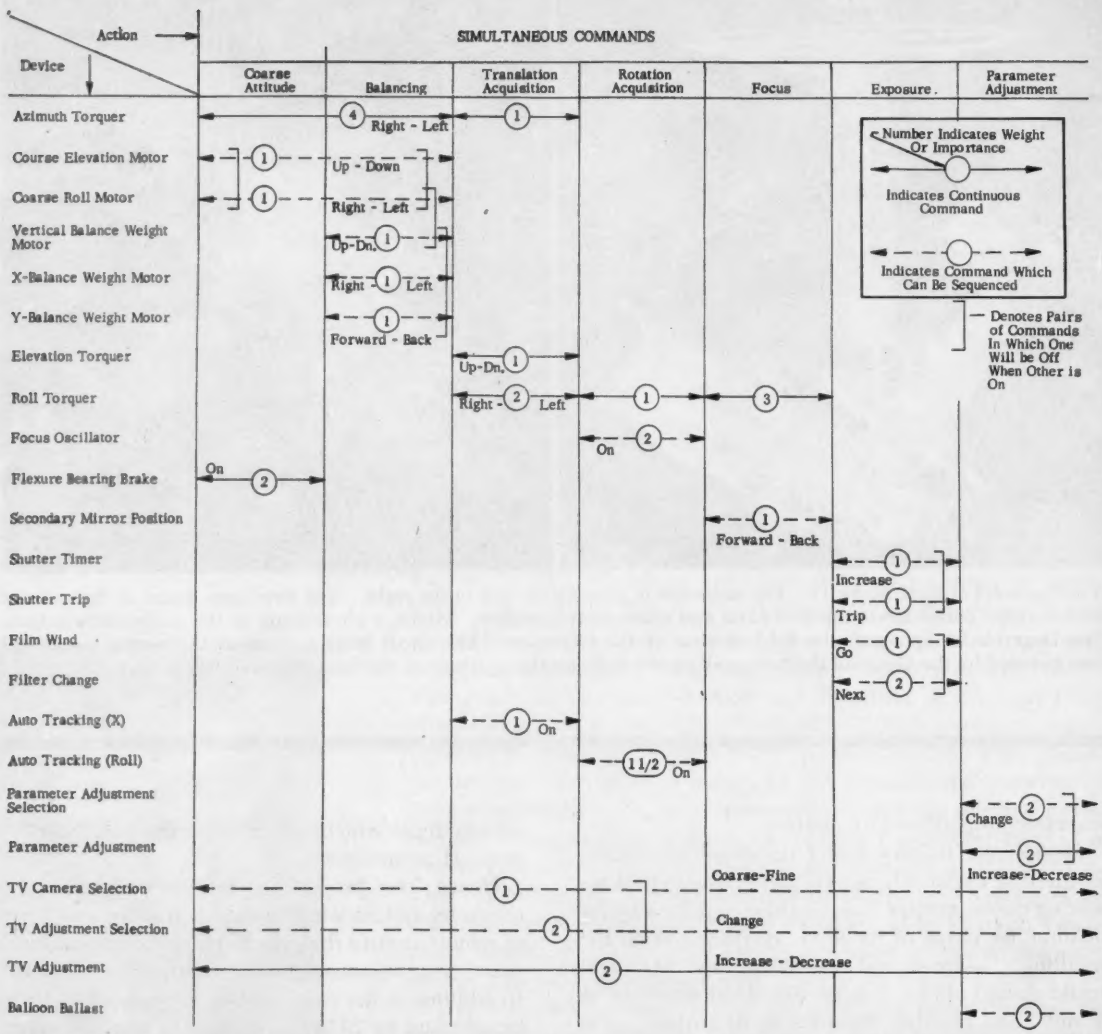
Stratoscope II, now being designed and manufactured at Perkin-Elmer, will have a theoretical resolving power greater than Stratoscope I by a factor of three by virtue of its 36-in. aperture. With the resulting $^1/_{10}$-arc-second resolution, Prof. Schwarzschild should obtain data on the cloud structure of Venus (and possibly glimpses of its surface), the nature of the atmosphere of Jupiter (with its mysterious red spot), an optical measurement of the diameter of Pluto, more information about the structure of Saturn's rings, and important data about the interior structure of galaxies and nebulae. Later, with the use of light amplifiers, there is the exciting possibility of observing the planetary systems of other stars. The project is again under the direction of Prof. Schwarzschild and Princeton Univ., sponsored by ONR, NSF, and NASA.

There is much more to the Stratoscope II project than simply raising a fine optical instrument to an altitude of 80,000 ft. In order to realize the good seeing possible at this altitude, it is necessary to hold the images stationary on the film to within $^1/_{100}$ of a second of arc during exposures, which will range in duration from 0.01 sec to 1 hr. This requires a fantastically accurate servosystem. No rotating or reciprocating parts are allowed to operate during exposure because internally produced vibrations will degrade image quality. If a man were carried on board to operate the instrument, even his involuntary motions would greatly overtax any existing servosystems which might meet the other Stratoscope II requirements.

Hence, the project requires a command and telemetry system which will permit a higher degree of remote control than has been carried aboard any space or near-space experiment attempted thus far. In addition, a television system is needed (and will be supplied by RCA) to permit the astronomers to identify objects and aim the instrument. All of the equipment must operate with the highest reliability at an altitude which couldn't be worse for electrical arc-over and in a temperature environment of —65 C. This temperature environment is more severe than satellite environment, because the instrument is to operate at night without the benefit of the solar heating which satellites enjoy on each orbit.

Operations in Several Phases

The tables on page 40–41 indicate operations during a Stratoscope II flight. It is planned that the balloon will be launched during the daylight hours (balloon launching is dictated by local meteorological conditions). When actual operations aloft start, they will fall into five or six phases, or modes, of operation: Initial startup (subsystems which consume large amounts of power are turned on just prior to use to conserve battery charge), a coarse pointing of the telescope on a separate gimbal pro-

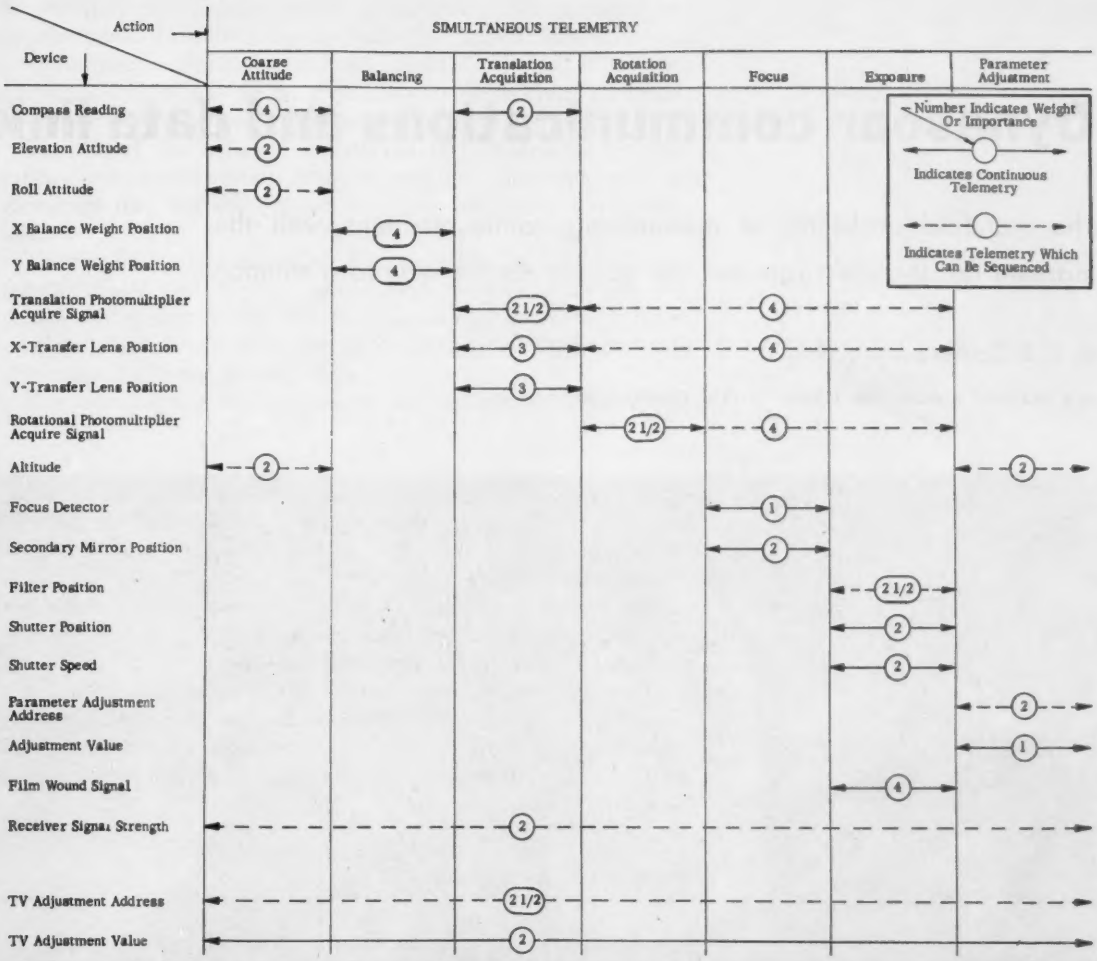


This chart shows all of the commands and the phase during the flight when they will be operated. The numbers inside the circles denote the relative importance of each command. The weighting scale ranges from "1" to "4," with "1" denoting flight failure and "4" denoting loss of convenience to operator if command fails.

vided for this purpose, a balancing operation (using the television picture to observe the apparent motion of the stars as the telescope swings on its flexure bearings in response to the unbalance), final pointing of the telescope (so that the images of the stars which provide guidance for the automatic tracking servo fall onto their respective image dividers), photography (including focusing), and, finally, set up for photographing the next object. The last step involves a sequence of gain changes in the pointing servos, some switching of functions, and adjustments to the position of the image-dividing prisms. During the entire flight, television adjustments must be possible at the same time any other operation is underway. There are a total of 15 television adjustments.

Two of the operations which the astronomers will perform using the command and telemetry system deserve special mention. These are the final, fine pointing of the telescope, so that the automatic tracking servos can operate, and the focusing operation.

The retouched photo on page 39 shows the field of view which the astronomer will see through the telescope on his television display. The square in the center represents the film, and the circles represent the aperture of the tracking servo's image dividers, all to scale. Since torque motors are used to point the telescope when it is hung on its flexure bearings, the astronomer's commands cause constant angular accelerations or decelerations of the telescope. This operation was simulated on an analog computer using a closed-circuit television display; to the writer this "fine acquisition" was much like



This chart shows the adjustments which must be observed through the telemetry system and the phase during the flight when this observation must be made. The numbers inside the circles denote the relative importance of each item: "One" an item causing flight failure if telemetry fails, "four" an operator convenience.

the child's toy in which you tilt the box to get the BB's to run into the little holes. On our simulation, acquisition could be accomplished in from 10 to 30 sec, and almost unbelievably low velocities at lock-on could be achieved.

Focusing by Secondary Mirror

Focusing cannot be done by simply watching the television picture because the television resolution is not good enough. The focusing element is the secondary mirror, and it must be positioned to within ± 8 microns (or 31.5×10^{-5} inches) of perfect focus. This is done by observing the response of the tracking servos to a perturbing signal as the focus is changed. Since the "gain" of the servo changes as the image at the image divider becomes more or less blurred, the amplitude of oscillation of the servo is an indication of focus condition. The secondary mirror is set so that the amplitude of oscillation is at a minimum.

As an engineering design problem, the choice of a command and telemetry system configuration was an interesting one. Since such a large portion of the telescope control originates on the ground, the system must possess high reliability above all else. The components were to be commercially available because neither time, money, nor the priorities of national defense permitted development of components specifically for the project. Finally, the components chosen had to be inexpensive, since university research, even when supported by Government funds, does not allow (CONTINUED ON PAGE 98)

Dynasoar communications and data link

The manifold problems of maintaining communications with the manned boost-glide space vehicle appear on the way to a solution

By L. B. Garrett Jr.

RCA DEFENSE ELECTRONIC PRODUCTS DIV., CAMDEN, N.J.

THE DYNASOAR communications and data-link subsystem (CADL), being developed by RCA for the Air Force, will support the vehicle in its first tests—ground launch at the Atlantic Missile Range and air launch at Edwards AFB.

The Dynosoar vehicle consists of a two-stage Titan booster plus the glider and associated transition hardware. The glider will be used during both air- and ground-launch tests.

It will be detached from a mother plane for air launch, in a manner similar to that used with the X-15, and will be designed to verify terminal-phase flight characteristics, including a first-order operational check of electronics, with communications and tracking maintained via CADL.

L. B. Garrett Jr. is leader, Dynasoar Project Office Systems Engineering, RCA Defense Electronic Products. Joining RCA after receiving a B.S. in electrical engineering from Drexel Institute of Technology in 1953 (also M.S.E.E. in 1958), he worked on the design, development, and production of the AN/ARC-34, specializing in frequency-synthesizing systems and receiver tuners, and on the AN/ARC-62 design and development program, specializing in receiver development. He has participated in coordination of the USAF time-division-data-link program, served as project engineer on command and long-range data links developed under USAF contract, and has been responsible for technical direction of communication studies for orbital military systems.

Plans Made for Testing

Ground-launch tests at the Atlantic Missile Range will employ the two-stage Titan to boost the glider to suborbital altitudes with very high burnout velocities. Several unpiloted flights are planned in 1963 to verify pilot-safety features. Piloted flights involving reusable gliders will follow the unpiloted flights by 1965.

The chief function of CADL is to provide the continuous in-flight transmission facilities required by the glide vehicle for radio communication and tracking.

Specifically, CADL provides the following:

- Vehicle-to-surface transmission of pilot voice, flight-safety data, and scientific test data.
- Surface-to-vehicle transmission of range-safety commands, test-conductor voice, and flight-director commands.
- Vehicle position data in spherical coordinates.
- Rescue communication between pilot and search craft.

In its major functions, therefore, CADL provides a communication service for the other major electronic subsystems in the glider and on the surface. The tie between CADL and some of the other vehicle avionic subsystems is shown diagrammatically on page 118. As indicated on the diagram, the major users of CADL are the test-instrumentation, display, pilot, and guidance subsystems. The bulk of the traffic handling by CADL is derived from the test-instrumentation subsystem.

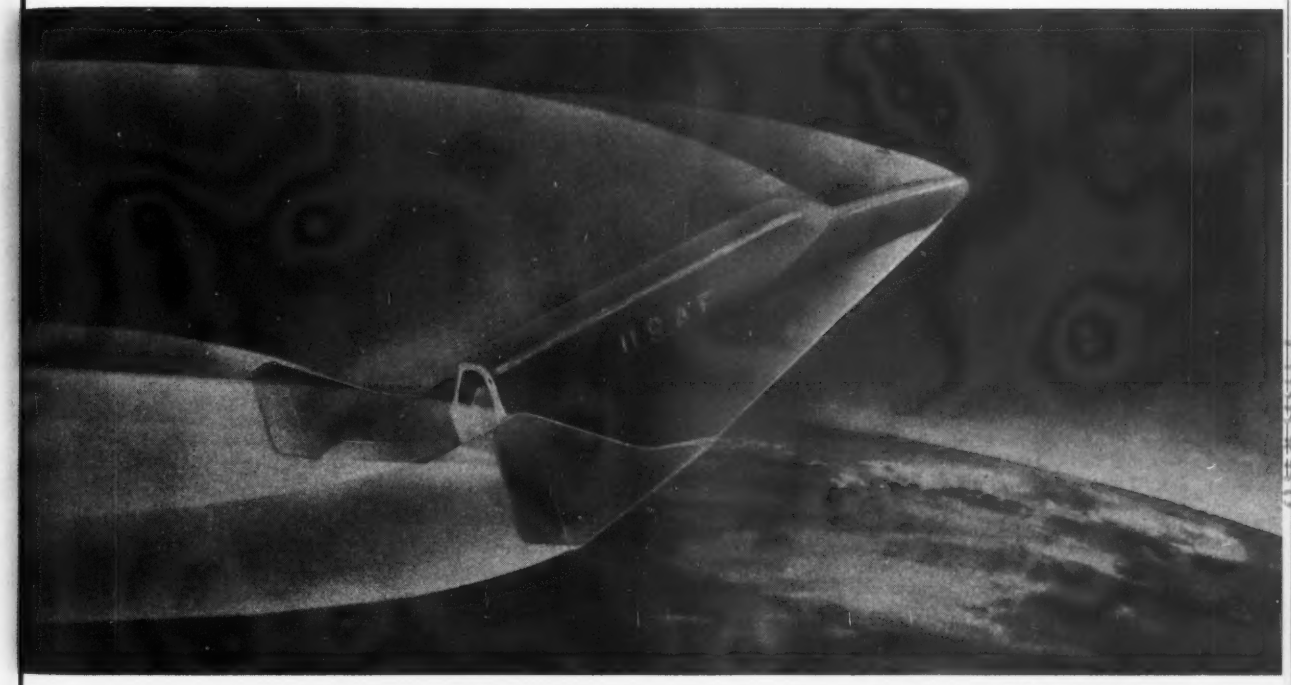
The telemetry data thus acquired falls into six general classes, one

of which is flight safety. The remaining are test and scientific data. Flight-safety data includes heartbeat, respiration, suit pressure, and accelerations. In addition to this kind of biomedical data, important temperatures, accelerations, pressures, and control-element positions are monitored to provide the capability for determining an unsafe glider condition which may endanger the pilot's life.

The second class is failure-analysis data, which includes temperatures, pressures, vibrations, attitudes, voltages, and equipment environment that will show major structural and avionics subsystem failures.

The remaining data classes are design-verification data, including detailed basic and applied aeronautical research measurements; vehicle and system design-refinement measurements; measurements involving data necessary for design of military equipment and subsystems; and geo-astrophysical data.

The multiplexing of this data in the test-instrumentation sub-



The Dynasoar glider, depicted here in re-entry, generates a host of communication problems—high skin temperatures, an ionized sheath, "where is it" at near-orbital velocities, etc.

system involves Pulse Code Modulation (PCM) and frequency-modulated subcarrier conversion equipment. The information received by CADL from this subsystem is in the form of serial PCM and frequency-modulated subcarriers. The bulk of flight-safety data is encoded into the PCM output.

The pilot requires the test-director voice signals from CADL, and to CADL supplies his own voice replies intended for the test director. In the event that the pilot must leave the vehicle, he carries with him rescue communications equipment. This equipment includes a beacon to assist search and rescue craft in locating him. In addition, the rescue group permits him to carry on two-way voice communication with such craft.

Command or advisory data which supplement voice instructions to the pilot are provided by CADL to (CONTINUED ON PAGE 117)

Adaptive aerospace PCM telemetering

The need to telemeter data continuously as a spacecraft moves from earth to space prompts the design of advanced PCM systems

By John O. Bowers Jr., Donald H. Ellis, and James M. Walter Jr.

DYNATRONICS INC., ORLANDO, FLA.

John O. Bowers Jr., a Dynatronics staff engineer, has recently been engaged in design of tansistorized digital data-handling systems and circuitry. After receiving a B.S. with honors in electrical engineering from Michigan State in 1953 and an M.S.E.E. from Purdue in 1955, and serving a two-year period in the Army as a radar officer on the AFCS M-33 system, he joined Cook Research Laboratories, designing airborne electronic circuitry, and then, before joining Dynatronics, worked in Vitro's Systems Development Dept. on design of long-range digital communications.

Donald H. Ellis is a senior project engineer for Dynatronics, responsible for design and development of aerospace PCM systems within its Data Systems Section. After receiving a B.E.E. from Clemson College in 1951, he worked with the Atomic Energy Div. of the E. I. du Pont de Nemours Co., the MIT Lincoln Laboratory, and Radiation, Inc. His experience includes design and development of nuclear-reactor control instrumentation and coincident-current magnetic-core memories, and serving as project engineer on airborne data-acquisition system development.

James M. Walter Jr., a Dynatronics staff engineer, is engaged in the development of designs for PCM telemetry systems. He received a B.E.E. from the Univ. of Florida in 1956. His work in industry has included design of digital data-acquisition systems and transistor circuits, with emphasis on programmers and multiplexers.

The authors wish to acknowledge the important contributions to the Adapt program made by R. P. Bishop, R. E. Gilbreath, J. T. Murphy, S. D. Fritch, B. W. Worral, and J. R. Dean.

A SINGLE PCM telemeter may be required to transmit data from a space vehicle continuously from prelaunch to deep space. Efficient use of such a telemeter necessitates varying system parameters at certain specified times during the flight of the vehicle.

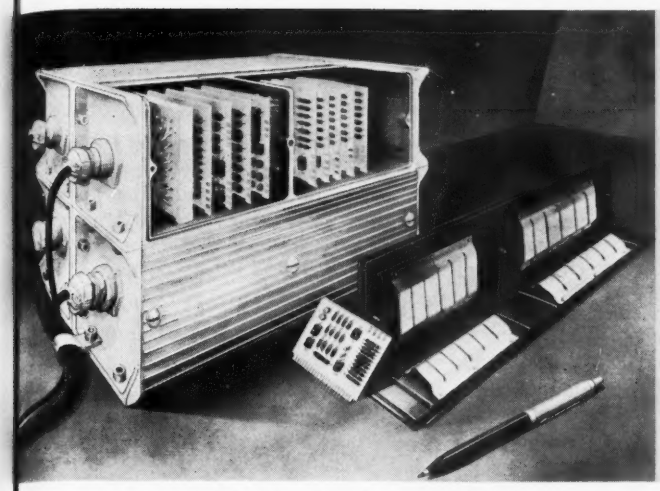
Consider, for example, this operation for a mission in which the space vehicle moves directly away from the earth. The vehicle proceeding farther away from the earth causes the retrieval of data to be more difficult. The system parameters of transmitter power and bit rate must be controlled to compensate for increasing distance of signal transmission. In programming the flight, it has been determined that logically the mission may be separated into three phases designated "launch," "near," and "far."

Transmitting Power Increases With Each Phase

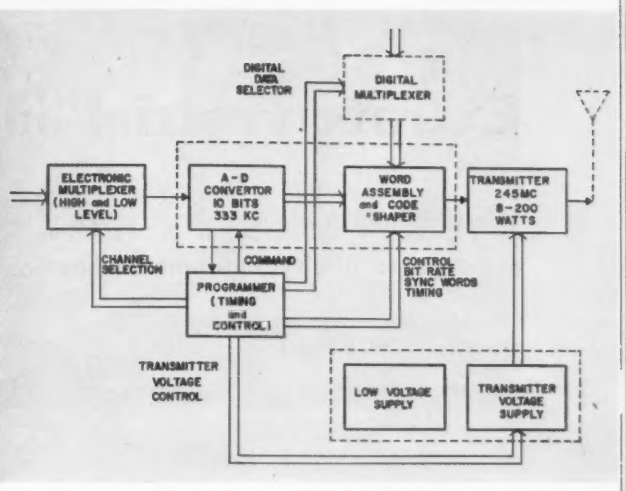
Boosters are separated during the "launch" phase. Many data points are monitored to note the cause of possible flight failures. The bit rate may be high, since the vehicle is relatively close to the earth for the launch phase compared to succeeding phases. Transmitter power output is low at liftoff, is sequentially advanced to higher power settings, and reaches maximum output near the end of the phase. Here, a long synchronization word may be needed, because the data format is relatively large.

Most of the volume of experimental data may be acquired in the "near" phase of the flight. The outer bound of the phase has been determined by compromise between the amount of data to be acquired and the system capability. Bit rate is set at medium value. Since the launch data points have been disconnected by booster separation, the "near" phase format contains fewer data points and new data sources not monitored previously. The synchronization pattern is shorter due to the smaller number of data points. Again, transmitter power, which had been reduced to a low setting at the beginning of the phase, is raised in steps to maximum output near the end of the phase.

The "far" phase is the last segment of the mission from which data may be received. Here, bit rate is reduced to the minimum value. Only a few data points, all of high priority, are to be acquired. The synchronization pattern length is reduced considerably, since the data cycle has been reduced. Data word lengths are minimized



Complete Four-Section Telemetry Package



Block Diagram of Basic System

consistent with the information to be acquired. During the phase, transmitter power is recycled from the initial low setting to maximum output as required. The limit of the "far" phase is the maximum distance from which intelligible data may be received with the combination of minimum bit rate and maximum transmitter power.

Such tasks have been the subject of a program being conducted for the Air Force (WADD), and have led to the experimental telemeter design described here as Adapt—the adaptive aerospace PCM telemeter.

The Adapt system is the result of a program to determine practical limits on the variation of the system parameters, in three major areas of interest. The work includes optimization of the programming, RF modulation, and packaging characteristics of PCM telemetry for varying requirements of test vehicles. The variable parameters include bit rate, format, and transmitter power. Control of the variable parameters may be timed, commanded, or linked to changes of configuration occurring during various phases of the vehicle flight.

Varying the Program Parameters

The program format parameters that may be varied are word length, number of channels (prime, super, and sub), channel sampling-rate, the measurands, digital words, and sync words. Expandability is another objective. This feature will permit the amount of hardware to be varied according to the demands of a particular mission.

To begin, then, for an optimum system the probability of error of the bits must be maintained within reasonable bounds. The probability of error is given by the following expression:

$$Pe = \int_{\left(\frac{kP_t}{BD^2}\right)^{1/2}}^{\infty} \frac{1}{(2\pi)^{1/2}\epsilon^{-}(+2/2)dt}$$

where P_e is the probability of a bit being in error, P_t is the transmitted power, B is the bit rate, D is the distance between the transmitting and receiving antenna, and k represents all other factors in the expression. Within the aerospace system, transmitted power and bit rate may be adjusted to compensate for changes in distance. The value of the limit varies as the reciprocal of the square of the distance unless the transmitter power and bit rate are varied sufficiently to keep the value of the limit constant.

Thus, for a long-range system, a tremendous range ratio of the value of P_t/B is required. For reasons of power efficiency, the range over which transmitter power may be varied is relatively small. Bit rate, however, may be varied over a considerable range. System bit rate is interdependent with the amount, precision, and frequency of data to be acquired. Therefore, program format and bit rate must be considered from several points of view, including mission requirements, equipment capabilities, and transmission-link limitations.

Certain compromises must be made between system flexibility and system complexity. Consider the limitations governing the number of prime channels to be provided. The type of programming circuitry required to produce prime channel gating pulses does not lend itself well to a modular expansion concept, wherein a number of identical modular units may be cascaded to achieve a desired prime channel capacity. An effort in this direction has been made, and it was found that a certain amount of circuit redundancy is (CONTINUED ON PAGE 124)

Extraterrestrial linguistics

Vacate! Negotiate! Work! . . . What will we say, if we can find a way to say it, to alien intelligent beings we may discover in the universe?

By Solomon W. Golomb

NASA JET PROPULSION LABORATORY, PASADENA, CALIF.

The recent Brookings Institution report to NASA on the potential consequences from our space explorations turning up evidence of alien intelligent beings in the universe includes the possibility of an all-out effort by us to contact them. This raises the question, How do you communicate with the Aliens and what do you say? Solomon W. Golomb, assistant chief of the JPL Communication Systems Research Section, here addresses himself to this question. At JPL, since 1956, Dr. Golomb has been concerned primarily with the application of discrete mathematics to coding and communications. He received an A.B. in mathematics from Johns Hopkins Univ. in 1951, an A.M. from Harvard Univ. in 1953, and, after spending the academic year 1955–56 in Oslo, Norway, on a Fulbright grant, a doctorate from Harvard in 1957.

THERE are two questions involved in communication with Extraterrestrials. One is the mechanical issue of discovering a mutually acceptable channel. The other is the more philosophical problem (semantic, ethic, and metaphysical) of the proper subject matter for discourse. In simpler terms, we first require a common language, and then we must think of something clever to say.

As far as the channel is concerned, there would seem to be many different possibilities. On earth, we can communicate by speech (using the ear as the receptor), by writing or semaphore and pictographs (using the eye as the receptor), by tactile means (e.g., Braille), and, as demonstrated recently, by modulating an olfactory channel (aromarama). Electromagnetic relaying being involved or not, any message we receive must ultimately activate one of our many sense perceptions—sight, hearing, touch, smell, taste, temperature, equilibrium, pressure, acceleration, etc. There is also conceivably telepathy, or at least alpha-rhythm.

If we met a strange creature on an alien planet who seemed to be capable of intelligence, it could be quite difficult to decide which of the many sounds (whistles, clicks, snaps) or smells (of which we have no theory to speak of) or radiations at many frequencies (possibly, but not necessarily, including optical frequencies) would be information-bearing. It could turn out that none of these are significant, but that behavior patterns such as fluttering of appendages and agitation of membranes tell the story, as in human discourse, where gestures and glances can easily replace words. On our own planet and within our own species, there have developed such diverse systems as sign, whistling, and gesturing languages (not only in Southern Europe, but in such constructs as the deaf-mute language), not to mention Morse, Semaphore, Braille, and spoken languages using quite dissimilar phonemes and intonation patterns. How to recognize an attempt to communicate something, when you first encounter it, might prove quite a difficult matter.

Of course, there is the approach of Project Ozma. If we start with as many assumptions about the reasonableness of our friends, the Extraterrestrials, as UFO enthusiasts do, we might end up with English-speaking anti-Communist white-Protestant Centaurians. Relaxing the constraints slightly, we find humanoids who build the same kind of radio systems we do, and who think and act much as we, even to the point of recognizing the 21-cm hydrogen line as the best of all possible frequencies. However, they are more interested

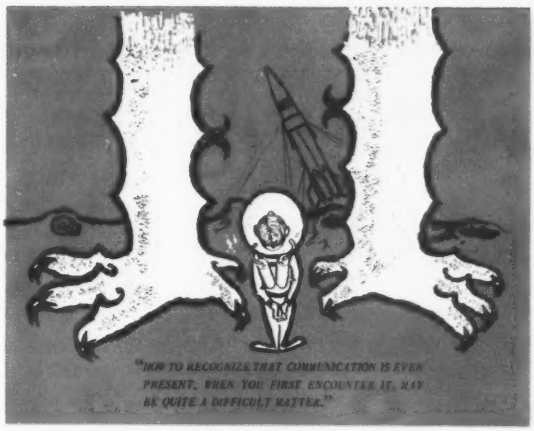
in us than we are in them, which is why they are transmitting, whereas we are merely receiving.

It would be wonderful, indeed, if this approach would lead to success, but 100-to-1 would be good odds that no results will be obtained by Ozma in time to affect my intention to retire from active space probing in the year 2000. After all, if they are as similar to us as all that, they have a budget-minded Congress which has set their peak transmitter power level just below our minimum detectability threshold, if it hasn't cancelled the project altogether for having failed to produce results for lo! these many millenia.

It would be particularly ironic if our portion of the universe is densely populated with gigantic receiving antennas, but with no one willing to undertake the additional expense and round-trip delay time required for transmitting. The conservative assumption is that, even if there is other intelligent life in our neck of the galaxy, we will not find it until we have brought a spacecraft fairly close to it.

Who's Intelligent?

Suppose that we have landed on or near some congenial planet, and we find there a species living in elaborate cities, and hence prime suspects in our quest for new intelligence. The mechanical problem of finding a mutually acceptable channel for the commencement of negotiations cannot be divorced from the semantic problem of convincing these creatures that *we* are intelligent. The solution to this problem depends on whether we are truly



face to face with the creatures, or merely have a narrowband link in operation. The narrowband link, being more constrained, is easier to analyze. For it, we want a pattern too regular to be random noise, but too irregular to be a naturally produced pulsation phenomenon. Standard suggestions include the binary expansion of the number *pi*, the sequence of the first few prime numbers, or simple arithmetic, such as "3 + 4 = 7."

To begin with, it is probably rank terrestrial provincialism to expect others to attach the same importance to *pi* that we do. Even in our own mathematics, such constants as *e* and *log 2* are considered important, and the exaggerated role of *pi* stems largely from the Greeks' undue efforts attempting to square the circle. Doing arithmetic has the drawback that such concepts as "plus" and "equals" must be brought into the picture.

My own recommendation is the prime sequence 2, 3, 5, 7, 11, 13, 17, 19, 23 . . . , with a long period to prove the nonaccidental nature of the signal. It isn't so much that I'm sure these Extraterrestrials would *recognize* the primes; but if they don't, they must be dull fellows, indeed, and I would just as soon not get acquainted. Of course, we use the base, 1, thus: 11 - 111 - 11111 - 1111111 - . . . We could equally well send portions of arithmetic progressions—for example, 1, 2, 3. . .; 1, 3, 5. . .; 1, 4, 7. . . . This makes fewest demands on pattern-recognition capability, and hence is a low-threshold intelligence detector.

The eminent Netherlands mathematician, Hans Freudenthal, is currently at work on a book to be called "Lincos" (for *lingua cosmica*), in which he will attempt to describe an ideal language for cosmic intercourse. This is all well and good, except that the Arcturists may be less interested in learning Lincos than in teaching us some equally ingenious invention of their own.

At closer range we can (CONTINUED ON PAGE 96)

Space Flight Report to the Nation Interim Report

SFRN preliminary program drawn

A TENTATIVE technical program for the October 9–15 ARS SPACE FLIGHT REPORT TO THE NATION, to be held in New York's Coliseum, has been outlined by George Gerard, program committee chairman. Five days of technical sessions to be held on the top floor of the N. Y. Coliseum will feature over 200 papers delivered in a total of 45 sessions, which are outlined in the chart below.

Six concurrent sessions have been scheduled in the mornings and on Monday and Tuesday afternoons. On the other hand, to accommodate maximum audiences, the special SPACE FLIGHT REPORTS panels will be the only sessions scheduled afternoons Wednesday through Friday.

The three concurrent panel discussions on Monday and Tuesday evenings have been designed to be of value to the specialist as well as of general interest.

The public will be invited to attend a panel on USSR space capabilities on Wednesday evening and a similar panel discussion on U.S. capabilities on Thursday evening.

There will be six separate sessions on communications and instrumentation as well as on electric propulsion. Four sessions on Missiles and Space Vehicles have been scheduled, with the remainder of the sessions divided among other disciplines.

On Saturday, a Careers Day program has been scheduled for students interested in becoming space scientists or engineers. Lectures and movies have been planned for the day-long career guidance program. ♦♦

PRELIMINARY SESSION SCHEDULE

	TENTATIVE Monday	Tuesday	Wednesday	Thursday	TENTATIVE Friday	Saturday
MORNING	Structures & Materials Communications & Instrumentation Nuclear Propulsion Test, Operations, & Support Propellants & Combustion Electric Propulsion	Human Factors Communications & Instrumentation Structures & Materials Power Systems Astrodynamics Electric Propulsion	Physics of Atmosphere & Space Communications & Instrumentation Missiles & Space Vehicles Hypersonics Liquid Rockets Electric Propulsion	Communications & Instrumentation Missiles & Space Vehicles Solid Rockets Guidance & Control Physics of Atmosphere & Space Electric Propulsion	MHD Space Law Missiles & Space Vehicles Solid Rockets Physics of Atmosphere & Space Guidance & Control	CAREERS DAY
LUNCH	"ARS and Space Objectives"	"Man's First Space Flights"	"The U.S. Space Program"	"International Space Activities"	"Challenge to Industry"	
AFTERNOON	Communications & Instrumentation Structures & Materials Nuclear Propulsion Test, Operations, & Support Propellants & Combustion Electric Propulsion	Communications & Instrumentation Power Systems Hypersonics Ramjets Missiles & Space Vehicles Electric Propulsion	**SPACE FLIGHT REPORT PANELS** The Vehicles	The Missions	Global Effects	
EVENING	Liquid Rockets Electric Propulsion Astrodynamics	Human Factors Space Law & Sociology Power Systems Panel	USSR Space Program Review	U.S. Space Program Review	BANQUET	

ARS Space Flight Report to the Nation

OCTOBER 9—15, 1961

Application For Hotel Accommodations

Please fill out this application form completely and mail it to:

Miss Sylvia Peltonen, Secretary
ARS Housing Committee
90 East 42 Street
New York 17, N. Y.

HOTEL	SINGLE	DOUBLE	TWIN BEDS
ABBEY, 151 West 51st St.	8.00- 9.00	10.50-12.50	12.50-14.50
*BARBIZON-PLAZA, 106 Central Pk. So.	13.50-15.50		17.50-21.50
*BARCLAY, 111 East 48th St.	15.50-21.50		23.50-27.50
*BELMONT PLAZA, Lexington Ave. & 49th St.	8.50-16.00	14.00-19.00	16.00-20.00
*BILTMORE, Madison Ave. & 43rd St.	8.00-20.00	15.00-25.00	15.00-25.00
*COMMODORE, Lexington Ave. & 42nd St.	8.50-16.50	14.00-20.50	15.00-23.00
*DIXIE, 250 W. 43rd St.	9.00-12.00	12.00-15.00	13.00-17.00
*EDISON, 228 W. 47th St.	8.00-11.00	13.00-18.00	15.00-21.00
*ESSEX HOUSE, 160 Central Park So.	All Space Reserved		
*GOVERNOR CLINTON, 7th Ave. & 31st St.	10.00-14.00	14.00-20.00	14.00-20.00
*HENRY HUDSON, 353 W. 57th St.	8.00-11.00	12.00-16.00	13.00-18.50
*MANGER VANDERBILT, Park Ave. & 34th St.	8.50-21.00	13.00-21.00	15.50-21.00
*MANHATTAN, 8th Ave. & 44th St.	9.00-14.00	14.00-18.00	15.00-18.50
*MAYFLOWER, Central Pk. W. & 61st St.	12.00-16.00		14.00-17.50
NEW YORKER, 8th Ave. & 34th St.	8.00-14.50	11.50-18.00	15.50-20.00
PARAMOUNT 235 West 46th St.	8.00- 9.00	10.00-12.00	12.00-14.00
PARK LANE, 299 Park Ave.	19.00	24.00	24.00
*PARK-SHERATON, 7th Ave. & 55th St.	11.00-16.00		15.00-20.00
*PIERRE, 2 East 61st St.			24.00-30.00
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*ROOSEVELT, Madison Ave. & 45th St.	8.50-20.00	13.50-24.00	17.50-25.00
*ST. MORITZ, 50 Central Park So.	13.00-16.00		16.00-20.00
*SAVOY HILTON, 5th Ave. & 58th St.	19.00		23.00
*SHERATON-ATLANTIC, Broadway & 34th St.	9.00-14.00	13.00-17.00	14.00-18.00
*SUMMIT, Lexington & 51st St.	14.00-30.00	16.00-32.00	18.00-34.00
TAFT, 7th Ave. & 50th St.	10.75		17.50
VICTORIA, 7th Ave. & 51st St.	9.00- 9.50	12.50-13.00	14.50-16.00
*WALDORF-ASTORIA, 301 Park Ave.	12.00-20.00	18.00-28.00	18.00-28.00
*WARWICK, 65 West 54th St.	18.00		22.00
*WELLINGTON, 7th Ave. & 55th St.	8.50-12.50	13.00-18.00	13.00-18.00
WOODSTOCK, 127 W. 43rd St.	7.00- 9.00	10.00-14.00	10.00-14.00

Rates subject to 5% New York City tax on hotel rooms. *Suites available. For reservations contact housing bureau.

---CUT ALONG THIS LINE---

Hotel Accommodations Desired. (It is necessary that five choices of hotels be listed below:)

INDICATE APPROXIMATE RATE AS SHOWN IN SCHEDULE		TYPE OF ROOM DESIRED		
CHOICE	HOTEL	SINGLE 1 PERSON	ONE DOUBLE BED— 2 PERSONS	TWIN BEDS 2 PERSONS
1st				
2nd				
3rd				
4th				
5th				

If accommodations are not available at any of the above hotels, reservations will be made at some other suitable hotel.

NAME.....

AFFILIATION.....

ADDRESS (Home/Bus.).....

CITY..... STATE.....

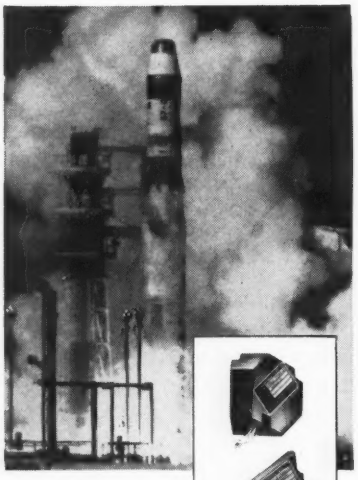
DATE ARRIVING..... ARRIVAL HOUR..... DATE DEPARTING.....

Please list names, affiliations and desired accommodations for additional persons on separate sheet and attach to this form.

NOTE: There will be an interval of several weeks before you can expect to receive a direct confirmation from the hotel accepting your reservation. Room numbers cannot be assigned by hotels until guests register on arrival.

MAKE YOUR RESERVATION NOW

Solution to critical temperature control problem on TITAN guidance platform



form-fitting control boxes fit small irregular space . . . temperature held to within a few hundredths of one degree

THE MARK OF QUALITY

BARBER COLMAN

Assignment to Barber-Colman Company from Air Force TITAN associate contractor, AC Spark Plug, Milwaukee: Take one part of the Air Force TITAN guidance platform and develop a complete temperature control system that will fit into the odd-shaped, very limited space available. Hold temperature to the exceptionally close tolerances specified. *Result:* A precision Barber-Colman temperature control system incorporating an ingeniously formed set of compact control boxes and sensing element (right) which control temperature of the internal structure to within a few hundredths of one degree. For help with your temperature control problems consult the Barber-Colman engineering sales office nearest you: Baltimore, Boston, Dayton, Fort Worth, Los Angeles, Montreal, New York, Rockford, San Diego, Seattle, Winter Park, Florida.

BARBER-COLMAN COMPANY

Aircraft and Missile Products Division

Dept. O, 1494 Rock St., Rockford, Illinois

Goddard Space Flight Center

(CONTINUED FROM PAGE 27)

haps unknowns of the cosmos.

Goddard's mission reads formally as follows:

- Advanced planning and theoretical studies leading to development of spacecraft for manned and unmanned scientific space investigations. This work includes formulation of concepts and ideas essential to the effectiveness of the NASA program.
- Supporting research in spacecraft, applications systems, instrumentation, communications, guidance, and rocket vehicles as assigned.
- Development and fabrication of spacecraft for scientific and applications programs and manned space flight. The Center designs, develops, and fabricates prototypes of components and systems to advance space technology or to foster practical applications. Although the Center directs all such work, most of it is contracted out to industry and universities. For reasons of economy, urgency, efficiency, or effectiveness, about 15% of such activities are performed internally by the Center.
- Development and supervision of worldwide tracking, data acquisition, communications, and computing operations for all NASA space programs except deep space probes.
- Interpretation of results of experiments under Goddard management.
- Management of projects, including technical direction and the execution and monitoring of contracts.

Heading its program is Dr. Goett, director, and Eugene W. Wasielewski, associate director; John W. Townsend Jr., assistant director for space science and satellite applications, supervising the Space Sciences Div. headed by Leslie H. Meridith, the Theoretical Div. headed by Robert Jastrow, the Payload Systems Div. headed by N. Whitney Matthews, and the Satellite Applications Div. headed by D. G. Mazur; John T. Mengel, assistant director for tracking and data systems, supervising the Tracking Systems Div. headed by C. A. Schroeder, the Data Systems Div. headed by Charles Smith, the Operational Support Div. headed by Fred S. Friel, and the Theory and Analysis Staff headed by Joseph W. Siry; Michael J. Vaccaro, assistant director for business administration; and Leopold Winkler, chief of the Office of Technical Services.

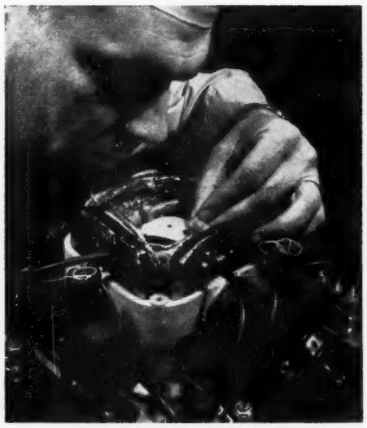
Goddard SFC considers its primary mission to be the scientific exploration of space. Since the characteristics of the earth's environment are determined to a large extent by other celestial bodies, this scientific exploration must include observations on a global scale. This automatically implies a continuing international scientific program. Consequently, scientists from GSFC have taken the initiative in expanding the worldwide cooperative effort in studies of meteorology, communications, astronomy, solar physics, and energetic particles by space vehicles.

International Projects a Goal

Typical of the major international projects being carried out under the guidance of GSFC scientists are the Tiros, Nimbus, and other weather satellites, ionospheric-beacon satellites, ionspheric topside sounding satellites, and the first United Kingdom satellite. In addition to these, there are many cooperative ventures in the area of sounding rockets, such as the recently announced joint experiments with the French Committee for Space Research.

In its role as program manager, Goddard, through its 2000-man staff of scientists and supporting personnel, and its facilities specially designed for space research, will be working closely with industry, universities here and abroad, other government groups, and the foreign organizations. ♦♦

ESG Prototype Readied by M-H



Inside the ceramic envelope at the center of this devicé, being tapped with a high-voltage lead by the technician, is the "first prototype" of Minneapolis-Honeywell's electrostatically suspended gyroscope, being developed by the company's Aeronautical Div. for the Navy, and scheduled to see service in the Polaris submarine navigational system. The camera-like objects on the main housing are optical pickoffs.

In the next decade, the United States is committed to an extensive program of space exploration. The Jet Propulsion Laboratory has been assigned, by the National Aeronautics and Space Administration, a responsibility for lunar, planetary and interplanetary un-manned exploration programs.

In the field of planetary exploration, the development and technology of automatic spacecraft and the gathering of scientific knowledge concerning the planets and their environment is involved.

By 1970, sufficient scientific data is to be acquired demonstrating the feasibility of spacecraft capable of orbiting and landing on Mars and Venus. In addition, programs will be initiated for probing Mercury and Jupiter and for further penetration into space.

The early Venus and Mars missions will utilize the Centaur launch vehicle and will constitute the "Mariner" series. These will be followed by the "Voyager" series employing the Saturn system.

The vast amount of information to be acquired, the scientific research and testing necessary, the new concepts to be investigated and the number of areas to be explored constitute an extensive long-range program. The challenge of probing the unknown, the vigor with which these problems are now being attacked and the demonstrated stability of the whole JPL operation provide career incentives for engineers and scientists in every field.

Here is an unparalleled opportunity for you for years to come — investigate now!

CALIFORNIA INSTITUTE OF TECHNOLOGY

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•

Plan and design integrated scientific instrument test systems. Plan and direct system testing of scientific instruments in conjunction with the spacecraft system testing and environmental evaluation.

•

Perform design and analysis of structures for spacecraft and for future advanced projects in part, or in whole. Responsibility for conducting structural tests during research and development period through final analysis portion of programs.

•

Work with research engineers and scientists as support instrumentation for studies on materials for rocket motors, space vehicles and space experiments—scope includes crystalline metallurgy, high temperature stress-strain measurements, induction and resistance heating.

•

Perform advanced development on liquid propellant rocket engines and gas generators to be used in lunar and planetary spacecraft. Effort includes both in-house work and technical direction of outside contracts.

•

Participation in the design, testing and evaluation of solar cell panels, development of laboratory sun-simulators —also includes development and evaluation of solar thermionic and thermo-electric systems.

•

Organize and conduct experiments on the containment of high temperature plasmas for ultimate possible use in propulsion and for studies in thermonuclear physics.

•

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MATHEMATICIANS

SYSTEMS EVALUATION POLARIS SYSTEM

The Applied Physics Laboratory of The Johns Hopkins University has responsibilities in the evaluation of the Polaris Missile System. We invite you to consider the following career appointments:

Senior Mathematicians

Duties will involve statistical analysis of complex test data for performance, reliability and operation evaluations. A background in physics or electrical engineering is desirable.

Project Engineers

For field test operations involving a team effort of Contractor, Navy and APL Personnel. Work will include launch and flight data acquisition analysis and monitoring of shipboard activities related to the Polaris Missile System. Prefer engineers with considerable background of project level responsibilities.

Systems Engineers

APL has several positions available on the associate and senior levels for men with experience in electrical engineering, physics, mechanical engineering, dynamics, or computer engineering. Will perform systems work related to fire control, navigation, missiles, and submarine controls. Assignment involves field work and contact with the Navy and Contractor Personnel.

Systems Analysts

Respondents must have heavy theoretical background and ability to read and understand telemetry records. Will perform basic analysis of systems related to fire control, navigation, missiles, and submarine controls. May also be required to simulate and solve orbit and doppler equations. Associate and senior level appointments.

Data Requirements, Instrument Engineers

Positions require a physicist or electrical engineer with experience in evaluation, data acquisition and testing of instrumentation installations. Will analyze sub-systems such as guidance, propulsion, controls, boosters, and inertial systems individually and as integral parts of over-all systems to derive data requirements and instrumentation. Duties involve some field work.

APL will provide you with a professional atmosphere conducive to creative effort as well as the tools and technical support required to tackle these and related problems. Our facilities are located in Silver Spring, a residential suburb of Washington, D. C., offering you a choice of country, suburban or city living.

For additional details, direct your inquiry to: Professional Staff Appointments

The Applied Physics Laboratory
The Johns Hopkins University

8609 Georgia Avenue, Silver Spring, Md.

U.S. Planetary Exploration

(CONTINUED FROM PAGE 25)

would furnish passenger room for interplanetary scientific experiments. A third developmental flight could be launched into an earth-return orbit to permit the testing of specialized items such as planet seekers and orientation equipment, planetary scientific instruments, and earthbound approach-guidance techniques.

In addition to the 1964 missions, additional Mariner flights are scheduled during the Mars and Venus opportunities in the years 1965 and 1966.

The first of the Saturn vehicle flights in the planetary-interplanetary program will be launched in the middle of this decade to begin the Voyager series. Possible missions for this initial flight include an advanced flyby, an orbiter, or a split-capsule lander. Beyond this time, the Voyager spacecraft is expected to evolve into a full series of sophisticated orbiters and landers, launched by the C-2 Saturn with Venus and Mars as primary targets.

Planetary orbiters are a necessary phase of the evolution because they are a logical step in the development of spacecraft technology; they are probably required to permit sufficient observation of the planet to determine locations and procedures for landing experiments; and they may constitute an important step in the actual landing experiment (orbital relay of information from the lander to earth).

Mariner Spacecraft

The preliminary design phase of the first Mariner spacecraft has been completed. The drawing on page 25 illustrates the spacecraft housed in the Centaur nose cone; the drawing on page 24 shows its spaceflight configuration; and the chart below right indicates a typical trajectory for a Venus mission.

The midcourse maneuver required for adequate flight path accuracy in the approach to Venus would be performed somewhat in the following manner. Accumulated perturbations and variances from the planned trajectory would be measured up to approximately 42 hr after launch. From this data, a corrective maneuver would be computed and transmitted to the spacecraft. A second command would direct the spacecraft to initiate the maneuver, and the following sequence of events would occur, in the order listed:

1. The antennas would be positioned to remove the high-gain directional antenna from the rocket-motor exhaust and to assure accurate CG location during firing.

2. The spacecraft gyros would be precessed to the calculated position for the maneuver, simultaneously causing the vehicle to follow the gyro precession.

3. The midcourse rocket motor would be ignited when the spacecraft oriented to the proper thrust vector.

4. Motor thrust would be terminated when the spacecraft incremental velocity, as measured by the integrated output of an axial accelerometer, equaled that of a velocity parameter previously transmitted as part of the midcourse maneuver command.

5. The antenna would be re-positioned.

6. The sun and earth would be reacquired and the proper spacecraft attitude re-established through the use of the attitude-control jets.

After completion of the midcourse maneuver, the spacecraft would again enter the cruise phase, which would be maintained until shortly before encounter with the target planet, Venus.

Typical scientific experiments to be carried on board the Mariner spacecraft for a Venus mission include the following:

1. Measurement of magnetic fields in interplanetary regions and in the vicinity of Venus.

2. Measurement of particles and high-energy radiation in the interplanetary regions and in the vicinity of Venus.

3. Measurement of mass and velocity distribution of dust particles in the interplanetary regions and in the vicinity of Venus.

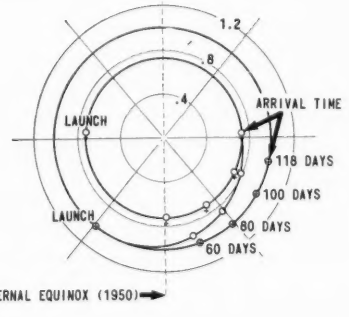
4. Study of atomic, molecular, and ionic species in the atmosphere of Venus.

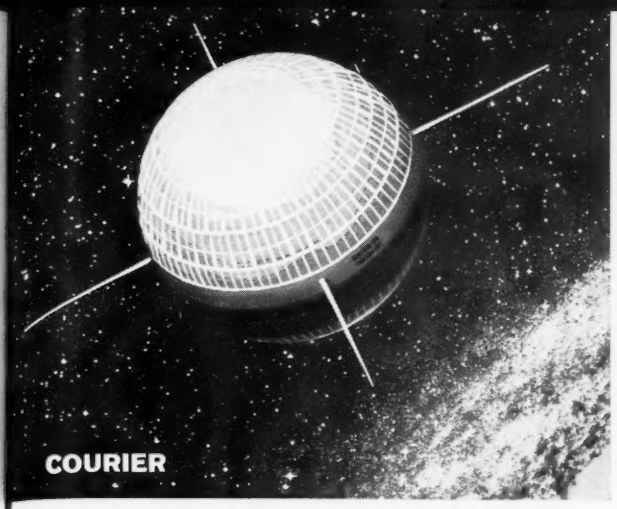
5. Measurement of temperature distribution on the surface and in the atmosphere of Venus.

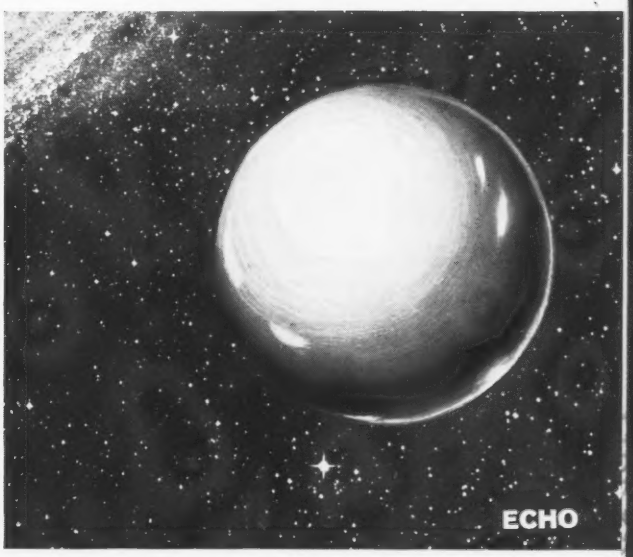
6. Deduction of as much of the physical properties of the surface of Venus from these measurements as possible.

A data automation system would be carried to provide a data programming

Mariner Flight to Venus







Philco Achievements in Space Technology

Philco has made many major contributions to the nation's vital space programs. COURIER, the world's first advanced communications satellite, was designed and built by Philco. Philco played a major role in the development and installation of the complex communications, command, tracking and data systems for the DISCOVERER program. Space-borne and ground communications systems for MIDAS and other satellites have been Philco designed. Philco developed and installed the tracking and receiving systems for the Air Force Passive Satellite Relay Link, which utilizes the ECHO satellite. In the field of human factors engineering, Philco has developed personnel subsystems for several major space projects. Philco also produces the world's largest 3-axis satellite tracking antennas.

These achievements are dramatic evidence of Philco's ability to integrate its extensive resources to the design and production of the most sophisticated electronic systems. For capacity, facilities and experience in space technology, look to the leader . . . look to Philco.

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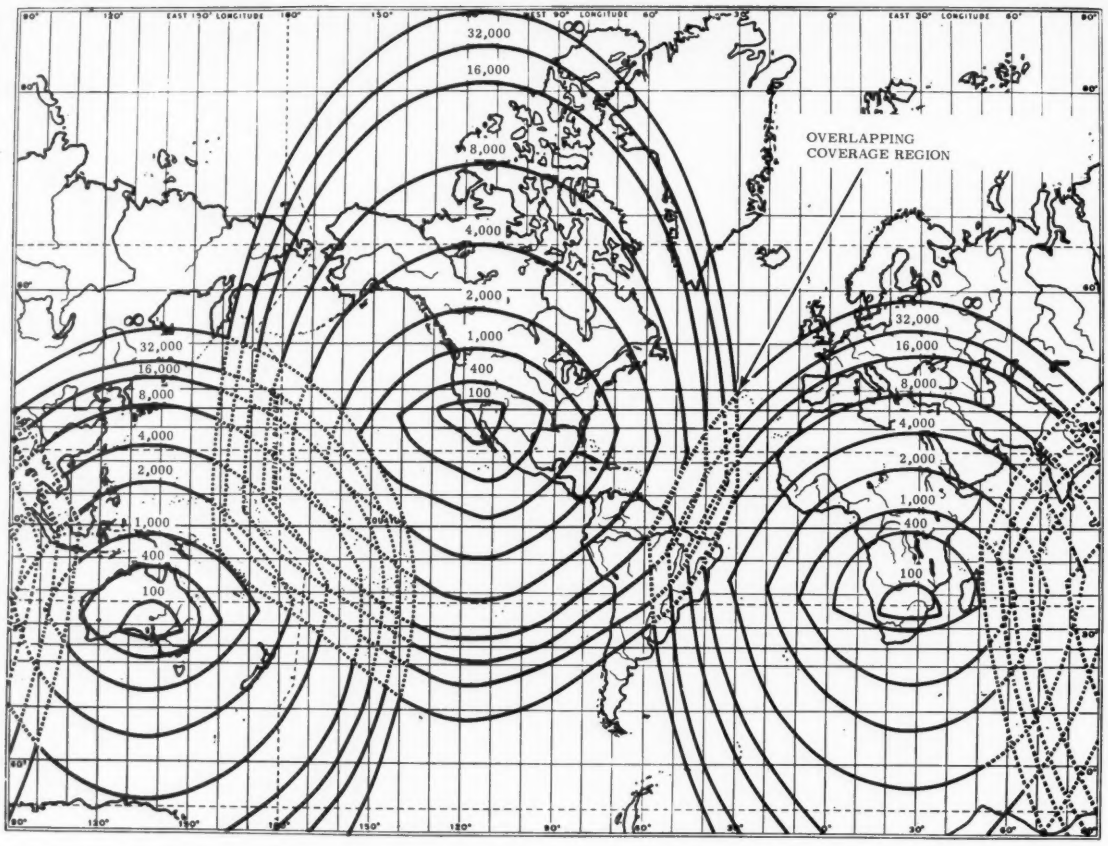
DSIF Coverage



Note: The chart gives the locus of subvehicle points for horizon visibility at given altitude in statute miles.

system for the scientific instruments as well as the required data storage. A predetermined program would be inserted into the automation system, with an automatic override to provide a suitable change in measurements if, for example, a solar flare should occur during the flight.

At the start of a typical planetary encounter sequence, the horizontal platform (an articulating, pointable head for the scientific instruments) would be oriented to the preset acquisition position, and antenna reference angles for the encounter would be established. The horizon scanner would then be placed in operation, planet search would be initiated and would continue until planet acquisition was accomplished, and planetary tracking would commence. The radiometer would be activated at approximately 150,000 km from the planet and would scan the target as the spacecraft passed. This experiment would continue to approximately 150,000 km past the planet. Scanning for the ultraviolet experiment would begin at about 60,000 km from the target and would continue through the encounter until the spacecraft was approximately 60,000 km past the planet. Nearest approach to the planet for this design would approximate 27,000 km.

Scientific data stored during the encounter would be transmitted back to earth on the two days immediately following the flyby. On the fourth day after encounter, an advanced development experiment could be performed, involving restart of the midcourse motor, with the spacecraft attitude such that the high-gain antenna could remain oriented toward earth during burning without entering the exhaust envelope.

Communications and Data Return

An integral requirement in scientific investigation of outer space is a precision tracking and communications system capable of providing coordinated tracking, command, and telemetering functions for the space probe. A Deep Space Instrumentation Facility (DSIF) has been established to satisfy this requirement of the lunar and planetary programs.

The DSIF net is comprised of three deep-space stations, one or two mobile stations, and the intersite communication links permitting data transfer and administration of operations. The DSIF stations are presently equipped with 85-ft-diam reflectors. A mobile station, equipped with a 10-ft-diam reflector, is used mainly for command, telemetering, and tracking of space probes from injection to over 10,000-mi altitude.

The DSIF design philosophy provides a precision radio tracking system for measuring two angles, radial velocity, and range, and then utilizes this tracking system to send radio commands and to receive radio telemetry in an efficient and reliable manner. The DSIF net is scheduled to undergo long-term improvement and modernization, consistent with advancement in the state of the art and spacecraft requirements.

In addition to its participation as a member of the DSIF, JPL's Goldstone station is utilized for extensive research and development in space tracking and communications, and, in most cases, new equipment will be installed and tested at Goldstone before it is integrated into the DSIF net.

The three deep-space stations are located at approximately equal intervals of longitude around the earth, as shown in the table on page 24. The mobile station will be emplaced near the mission injection points, which tend to be centered in the southern hemisphere.

The loci of subvehicle points with 5-deg horizon mask angles at Woomera and Johannesburg, and the natural mask at Goldstone, are shown on page 54. This figure indicates the field of view of each deep-space station as a function of vehicle altitude, and it also shows the regions of overlapping coverage. The field of view of mobile stations is usually unrestricted because of normal emplacement in elevated locations.

Technological Problems

Some of the more significant technological barriers peculiar to the planetary-interplanetary program are as follows:

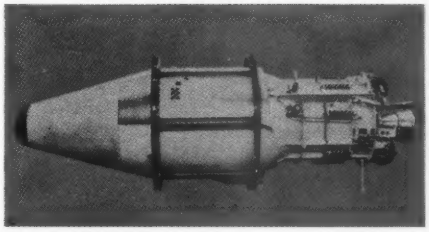
Launch on Time. This problem cannot be overemphasized. The launch-on-time restraint means that schedules *must* be met and that equipment *must* be reliable, both in prelaunch operations and the flight environment. The equipment must also have the capability of simple checkout, and parameters must be easily reset, where necessary, so as not to restrict the launch window.

Long Life. The mission flight times even to the nearer planets will vary from a minimum of about 3 months to perhaps several years. Equipment obviously must be designed and built for long life under the extreme environmental conditions of space.

Power. Because of the long-life requirement and weight limitations, it is necessary, for at least the next several years, to use solar panels as the primary and sustaining power sources for spacecraft. Solar panels must be oriented toward the sun, with batteries occasionally backing up certain maneuvers. Use of more-or-less standard spacecraft for different missions toward and away from the sun imposes certain general engineering problems. For example, approximately two to three times as much solar collecting area for the same power is required in the vicinity of Mars as in the region of Venus.

Temperature Extremes. Passive emissivity and absorptivity surface-treatments are considered inadequate to permit spacecraft electronic equipment to operate for the required lifetime of a planetary or interplanetary mission under the expected temperature extremes. The design of suitable thermal-control systems for missions

FOR THE VITAL DISCOVERER PROGRAM



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Telemetry components designed and precision built by Dorsett Electronics will be aboard specially instrumented Lockheed Agena Space Vehicles to be flown in the Discoverer Satellite Program.

Lockheed Missile and Space Division is the latest in a long list of missile and satellite prime contractors to buy Dorsett telemetering components for advanced aerospace research programs.

Typical of the telemetering equipment originating at Dorsett Electronics is the Model 0-8 subcarrier oscillator. Requiring only 6 volts at .7 (nominal) milliamperes primary power, this all-silicon transistor unit provides excellent temperature stability for drift-free data. With its compact packaging, the Model 0-8 is ideal when electrical power is limited, space and weight are critical, and environmental extremes are to be encountered.

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toward and away from the sun poses a challenging engineering problem.

Communication. The communication distances for spacecraft in the vicinity of Venus and Mars will be on the order of 30 to 100 million miles; Jupiter and other targets will be appreciably farther. There is a need for efficient high-power transponders and for large yet stowable antennas with proper high-gain, directional characteristics. In flyby experiments, a considerable amount of data must be gathered in a brief time of encounter near the planet. This data can be stored during the encounter, but it may require days to transmit the same information back over the long communication path to earth.

Design Adequacy. Planetary opportunities are few and launch vehicles and spacecraft are expensive. Space exploration will not have the benefit of nearly as many developmental launchings preceding a particular mission as have military rockets and launch vehicles in the past. Fabrication and testing techniques must be thorough and well planned, and a very high order of reliability must be designed into the spacecraft.

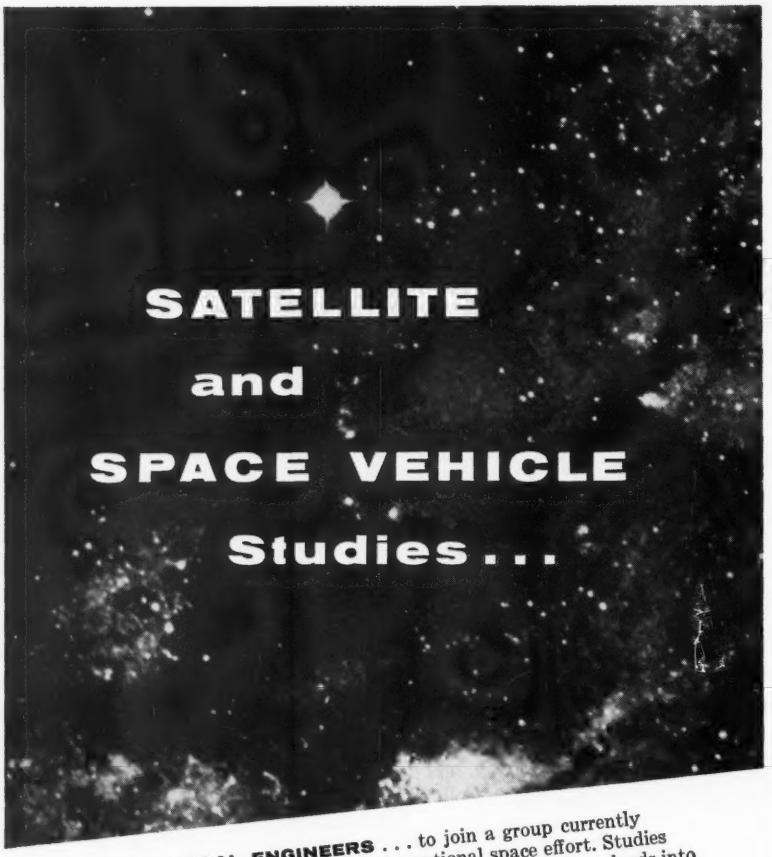
Sterilization. It is national policy to prevent the contamination of a target planet or its atmosphere by U.S. spacecraft. Although early missions are planned as intentional planet flybys, later landing or atmospheric-entry experiments will require development of effective sterilizing techniques, consistent with manufacturing and launching operations.

Instruments.. Families of instruments must be devised to conduct the exploration of space and the planets with the capability of flexibility of measurements. These instruments must be engineered with the same considerations of reliability, environment, and operational concepts that are given the other elements of the spacecraft systems.

By 1970, the U.S. planetary-interplanetary program should provide comprehensive knowledge of translunar and interplanetary space, and should make a vigorous start in probing the intriguing mysteries of the near planets and the extra-ecliptic regions.

Exotic new propulsion systems, such as nuclear-electric propulsion, will lift much heavier, more complex payloads and deliver them with extreme accuracy.

From these beginnings, the last 30 yr of the century may well bring man near the solution to some of the ultimate questions that have excited him since he first became aware of the environment beyond earth. ♦♦



ASTRONAUTICAL ENGINEERS . . . to join a group currently making significant contributions to the national space effort. Studies include determination of economical methods for boosting payloads into orbit; maximizing payloads for inter-planetary missions; determination of satellite arrays for full-time weather observations of the earth's surface.

Requirements include an advanced degree in Aeronautical Engineering, Astronautics or Mechanics with a strong background in Applied Mathematics. A knowledge of celestial mechanics is desirable.

PRELIMINARY DESIGN ENGINEER . . . for a group responsible for analytical studies of advanced vehicle concepts and their propulsion systems. Work will include the selection of structure types and estimation of structure and component weights for space vehicles, missiles, conventional aircraft, and VTOL's.

The position requires a background of experience with broad studies in which structural weights have been developed on a generalized basis. Advanced degree in Aeronautical Engineering preferred, although consideration will be given to a B.S. with extensive applicable experience.

Respect for individuality Our overall organization is small. Office areas are designed to provide an environment for mental concentration. Widely circulated technical reports bear the signature of those responsible for the study; publication of papers is encouraged.

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What can a skipping stone teach us about re-entry from space?

One promising approach to the problem of atmosphere re-entry is called the skip-glide path. The spaceship would follow an undulating trajectory, glancing off the atmosphere to lose its speed, much as a stone skips across the water. The necessary lift might be provided by a deployable pneumatic wing which would inflate on entering the atmosphere.

This and other approaches to aerospace deceleration are now being studied and evaluated at Northrop's Radioplane Division as part of its comprehensive program in landing and recovery systems. Long recognized as the leader in all aspects of paradynamics, Radioplane is fast becoming the industry's standard for space and aerospace landing systems. Active programs now include lunar soft landing studies, aerospace decelerators, and re-entry drag devices as well as recovery and landing systems for *all manned space vehicles actively scheduled by the U.S.*

RADIOPLANE
A DIVISION OF
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To Find a Flaw

This new 10-mev radiographic linear accelerator at the U.S. Naval Ammunition Depot in Concord, Calif., is now being used for X-ray examination of propellant-loaded Minuteman, Polaris, and Skybolt missile units. The first of its kind, this unique machine, designed by Varian Associates of Palo Alto, Calif., can locate tiny flaws through more than 6 ft of solid propellant. It incorporates 14 inventions not previously applied in accelerators, according to Varian. The first report on the machine's operation was made recently at Concord.

Orbiting Observatories

(CONTINUED FROM PAGE 37)

dependent sets of observing systems the mission will be a success by the operation of either system.

(3) These two systems are also complementary in their use of the spacecraft systems. The sky-mapping system will utilize primarily real-time data transmission, while that being designed by the Univ. of Wisconsin will utilize the data-storage capabilities of the spacecraft.

The investigations to be conducted in the first OAO are expected to provide astronomical data which will be of use to the entire community as well as an aid in designing later instrumentation.

The second satellite will contain the system being designed by a Goddard Space Flight Center team headed by James Milligan. This system will be used for absolute spectrophotometry. The optical system will employ a 36-in. primary mirror and will use both the coarse (1 min of arc) and the fine (1 sec of arc) control systems. Although the fine guidance will materially improve the program that can be conducted with this instrument, useful data can still be obtained for the life of the satellite even if this critical system does not operate.

The third observatory is intended for an investigation by Princeton Univ., under the direction of Lyman Spitzer. This experiment is concerned primarily with determining the absorption features of the interstellar medium. It thus places maximum requirements on the optical, thermal, and control systems.

It is expected that the fourth and later satellites will be used for studies of the sun and planets. In addition, there is a limited amount of payload capacity for small secondary experiments on the programmed satellites.

Observational Objectives

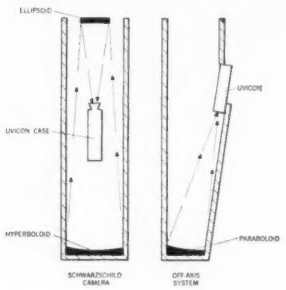
The primary objectives of the investigation to be conducted by the Smithsonian Astrophysical Observatory are to map the sky in the ultraviolet down to a wavelength of 1100 Å with three broadband television photometers and to record the brightnesses of at least 200,000 hot stars. A detailed discussion of this investigation has been given by Whipple and Davis.[1] The telescope for the sky-mapping photometers will probably be the Schwarzschild camera or an off-axis system. In any case, the configurations will be similar to those shown in the drawing on this page. The detectors that are presently under consideration are Westinghouse Uvicons. Each of the three detectors will be sensitive to a definite wavelength band: One from 3000 to 1700 Å, the second from 2000 to 1050 Å, and the third from 1600 to 1050 Å. (The shortwave cutoff is controlled by the faceplate material—lithium fluoride or quartz, for example.) It is tentatively planned to digitize the information from these cameras and transmit it to the ground stations in real-time. Thus this investigation will be conducted only during periods when the observatory is in contact with one of the three ground stations.

The observations to be conducted by the Univ. of Wisconsin are directed toward the determination of the stellar energy distribution in the spectral region from 3000 to approximately 8000 Å, and the measurement of emission-line intensities of diffuse nebulae in the same spectral region.[2] The instrumentation proposed consists of three basic photometric systems. The first is a multicolor filter photometer system intended primarily for star measurements. It consists of four 8-in. telescopes, each telescope feeding a separate three-color filter photometer. A second multicolor filter photometer system, intended primarily for nebular studies, employs a 16-in. telescope. A third system employing an objective-grating spectrometer is also under consideration. These instruments are depicted schematically in the series of three drawings here below. It is intended to store the information in a magnetic-core storage system in the spacecraft, and read it out during passes over the ground receiving stations.

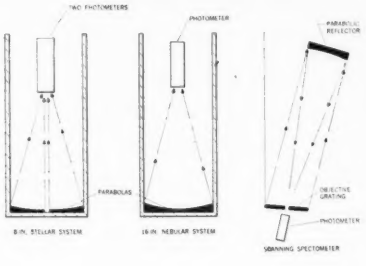
The objective of the investigation to be conducted by the Goddard Space Flight Center is to obtain absolute spectrophotometric data on selected stars, nebulae, and galaxies. The optical system will employ a relatively fast 36-in. Cassegrain telescope with a large-aperture spectrophotometer; the usable spectral region will be approximately 912 to 4000 Å. A tentative optical system is shown schematically on page 60. This investigation will require pointing accuracy in the neighborhood of 1 to 2 sec of arc, which is more stringent than the 1 min of arc provided by the basic spacecraft. It is expected that the fine-guidance sensors will be a part of the main optical system.

The primary objective of the Princeton experiment is to provide quantitative observations of the absorption spectrum of the interstellar gas in the

Sky-Mapping Telescopes



Photometric Systems



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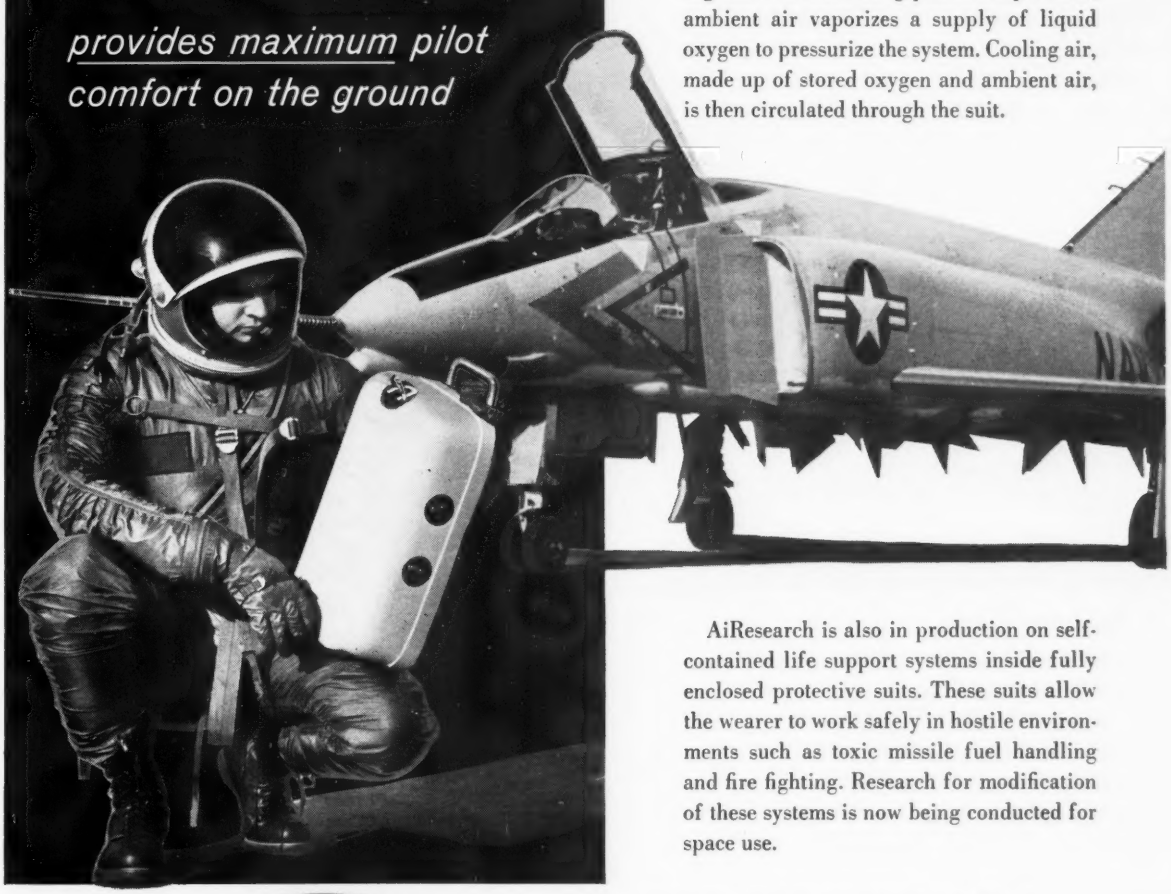
provides maximum pilot comfort on the ground



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AiResearch is also in production on self-contained life support systems inside fully enclosed protective suits. These suits allow the wearer to work safely in hostile environments such as toxic missile fuel handling and fire fighting. Research for modification of these systems is now being conducted for space use.

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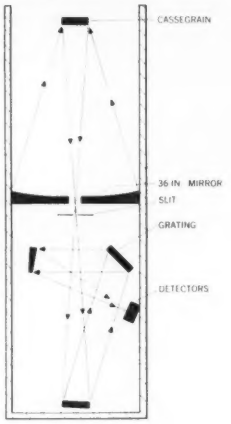
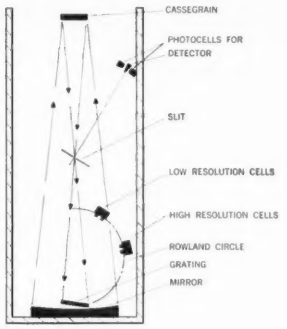
regions 800–1500 Å and 1600–3000 Å. Present theories hold that the stars are condensed out of clouds of interstellar gas and dust. It is eminently important, therefore, to understand the composition and physical conditions of these clouds. Since most of the interstellar atoms absorb only in the far-ultraviolet and virtually none in the visible, the study of the interstellar gas will be immeasurably advanced when observations are made in the ultraviolet with high dispersion. At present, the optical system consists of a Cassegrain reflecting telescope feeding a concave grating spectrometer, as indicated in the drawing at top right. The $f/3$ primary will be approximately 32 in. in diameter, and the detectors will scan the spectrum along the Rowland Circle, which is 1 meter in diameter. As presently conceived, the fine-guidance sensor, with the accuracy requirement of 0.1 sec of arc, is a four-sided pyramid with photocells looking at each side; the correct orientation is indicated by equal outputs from the four photocells.

Spectrophotometric System



Princeton Apparatus



Spacecraft

The present concept of the OAO spacecraft, being developed by the Grumman Aircraft Engineering Corp., is an octagonally shaped aluminum structure with a central tubular area containing the experimental equipment. The total weight of the spacecraft is expected to be about 3300 lb, of which 1000 lb is allocated to the experimental apparatus. Externally mounted solar arrays supply the needed electrical power. The stabilization and control system consists primarily of star trackers, sun trackers, rate gyros, inertia wheels, and gas jets. The remainder of the basic system is comprised of a data-storage unit, instrumentation to monitor vehicle operation, and the necessary communication links to provide commands for operating the spacecraft and the experiment, as well as to transmit experimental and operational data to the ground.

The satellite will be launched by an Atlas-Agena B vehicle from the Atlantic Missile Range, into an approximately circular orbit at an altitude of 500 st. mi. and inclined to the equator at an angle of 32 deg. This orbit altitude was selected to provide for operation below the Van Allen radiation belts and yet high enough to minimize external disturbance torques and to provide the required longevity of operation. The observatory will be operated from a central control center at the Goddard Space Flight Center, with transmission and reception from the spacecraft at three Minitrack stations linked to GSFC by teletype. Those selected will be Blossom Point, Md. (which has a microwave link to the central control center), and possibly Quito, Ecuador, and Santiago, Chile. These stations were selected to provide a "fence" to cover each orbit of the observatories as indicated in the chart on page 37.

The sequence of operational events following booster liftoff begins with the shroud separation after burnout of the Atlas stage. The spacecraft is injected into orbit by the Agena B vehicle, and the solar arrays are erected prior to separation from the Agena B. After separation, the rate gyros in the OAO stabilization and control system are used in conjunction with a gas-jet system to stabilize the satellite against random motions caused by separation. After being aligned by means of the sun sensors, so that the pitch (optical) axis is on the sun line, the satellite is rolled about the pitch axis until the star trackers lock onto a set of preselected stars. It will then be ready to accept commands and the observations can begin.

Configuration

The drawings on page 37 show the general arrangement of the OAO. The octagonal body of the satellite is 80 in. across the flats and 118 in. long, with a central tube containing mounting provisions for an experimental container 40 in. in diameter by 112 in. long. A sunshade is provided which can be positioned during orbital operations to prevent sunlight from entering the experimental package. The solar cells, mounted on four paddles which are retracted during launch and permanently extended after injection into orbit, are located in a plane that intersects the body of the structure at 33.75 deg. The solar cells are mounted on the paddles in a sawtooth arrangement at an angle of $22^1/_2$ deg to the plane of the paddle—a design which permits observation of all stellar objects except those within a 90-deg cone about the sun.

Structure

The basic structure of the spacecraft is a central tube which houses the primary optical package. Radiating from this structural cylinder are eight equally-spaced truss beams, terminating at the corners of the octagonal body, which provide the attachment structure for the solar paddles and the sunshade. These beams efficiently absorb all acceleration loads and transmit them to a circular base ring at the bottom of the OAO. This ring serves as the separation plane for the satellite. The outside surface of the spacecraft is covered by a segmented skin which serves as a heat shield and micrometeorite barrier.

Thermal Control

The thermal-control requirement of the OAO can be satisfied, it is believed, with a reliable passive system based on features of the satellite design such as surface properties, insulation, radiation shielding, and conduction paths. The technique consists of providing an isothermal environment for the optical system—quite an important consideration, since thermal gradients must be minimal, especially in high-resolution systems. To ac-

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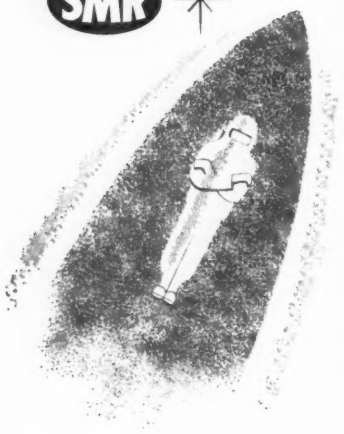

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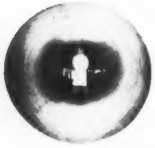
Photo of Rocket Chamber courtesy of Aerojet-General Corporation



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complish this, the outer-skin panels, whose surfaces have a low absorptivity-to-emissivity ratio, are not in direct thermal contact with the interior structure. Radiation from on-board equipment inward to the experimental tube is prevented by the use of radiation shields. Because of the random orientation of the satellite, consideration must also be given to the temperature limitations required by the on-board electronic gear. These will be controlled by means of radiation shields, conductive paths, and the grouping of components with respect to their duty cycles.

Stabilization and Control

The operational requirements imposed on the satellite's attitude-control system were evolved to achieve the accuracy and stability which the scientific mission requires of the observational equipment. The original concepts of a stabilization system for the OAO were investigated at the NASA Ames Research Center.[3]

Basically, the requirement is for a guidance and control system that will permit determination of the absolute direction of the optical axis to an accuracy of 1 min of arc and the orientation of the optical axis to 1 deg with respect to a known reference. Also, the control system must permit an ultimate guiding accuracy of 0.1 sec of arc during observation of an individual star. The error signal for this fine control will be generated within the prime optical system.

The major function of the attitude-control system may be categorized into three tasks:

1. To stabilize the spacecraft following booster separation and to establish its attitude with the required precision.

2. To slew the satellite to any desired attitude, as dictated by the scientific objectives of the mission.

3. To enable the satellite to maintain a given attitude with the required accuracy over long periods of time.

The spacecraft will utilize three rate gyros to sense the initial tumbling rates after separation and to provide control signals to reduce these rates to zero. A set of solar sensors are provided for initial orientation or re-orientation relative to the sun. The primary orientation system, however, is a system of six star trackers, two on each axis. These are mounted in 2-deg-of-freedom gimbals to cover as large a solid angle as possible. A television system will also be employed as an additional attitude-determination system.

The actuation system consists of two sets of inertia wheels and a gas-jet system employing nitrogen as a propellant. The large inertia wheels will be used only for slewing or re-aiming the satellite from one observational target to another. The fine wheels, which will be used to stabilize the satellite, must have sufficient momentum capacity that they will not become saturated in less than the time of $1^1/_2$ orbits, since an observation can last that long and stabilizing motions must be deferred during observations.

In addition to providing initial stabilization, the gas-jet system will be used to remove the momentum from the fine-stabilization system.

Communication and Data Storage

The communications system of the OAO includes four radio links which are required to accomplish tracking, command, and telementry. Programmed commands will be sent from the Central Control Center via one of the Minitrack stations to the satellite. These commands, in the form of pulse-code modulation, can be used in real time or they can be stored to accomplish re-programming of the satellite or experimental operation at a later time. There will be two telementry systems. A narrowband PCM system operating at 137 mc with at least 200 channels will have a data rate of 1000 bits per second, and a wideband system at 400 mc will have a data rate of at least 10,000 bits per second and a 250-kc bandwidth for analog signals. Storage for experimental data, with a redundant capacity of 100,000 bits, will be provided by a magnetic-core memory device.

Power Supply

The power supply for the OAO is a fixed array of silicon solar cells used in conjunction with rechargeable nickel-cadmium storage batteries. An average power of 215 w is available from the array, with power available to the experimental equipment at 30 w average and 60 w peak.

This, in brief, is an outline of the scientific objectives of the OAO Project and the present plan of implementing these objectives. The satellite has guidance and stability requirements exceeding those of any other proposed spacecraft, and a command system for operation of the spacecraft and observational equipment that is unique in comparison to present systems.

References

1. Whipple, Fred L., and Davis, Robert, "Proposed Stellar and Interstellar Survey," *Astron. J.*, vol. 65, no. 5, pp. 285–290, June 1960.

2. Code, Arthur D., "Stellar Astronomy from a Space Vehicle," *Astron. J.*, vol. 65, no. 5, pp. 278–284, June 1960.

3. Triplett, William, "Design Considerations for An Orbiting Astronomical Observatory," American Rocket Society Preprint 1184–60, Semiannual Mtg., Los Angeles, May 1960. ♦♦

Tiros Program Results

(CONTINUED FROM PAGE 29)

addition, there were three achievements in different technological areas which are worthy of specific mention:

a. *Spin-up rockets.* In Tiros I, approximately seven weeks after launch, a pair of spin-up rockets were successfully fired on command from the ground to improve the spin-axis stability. The spin rate was increased from 9.5 to 12.85 rpm (the design increase value was 3 rpm). This was the first known demonstration of a rocket motor on any satellite or space vehicle being fired successfully after such a long period in the space environment. In Tiros II the spin-up rockets were again successfully used, although this time only two days after launch.

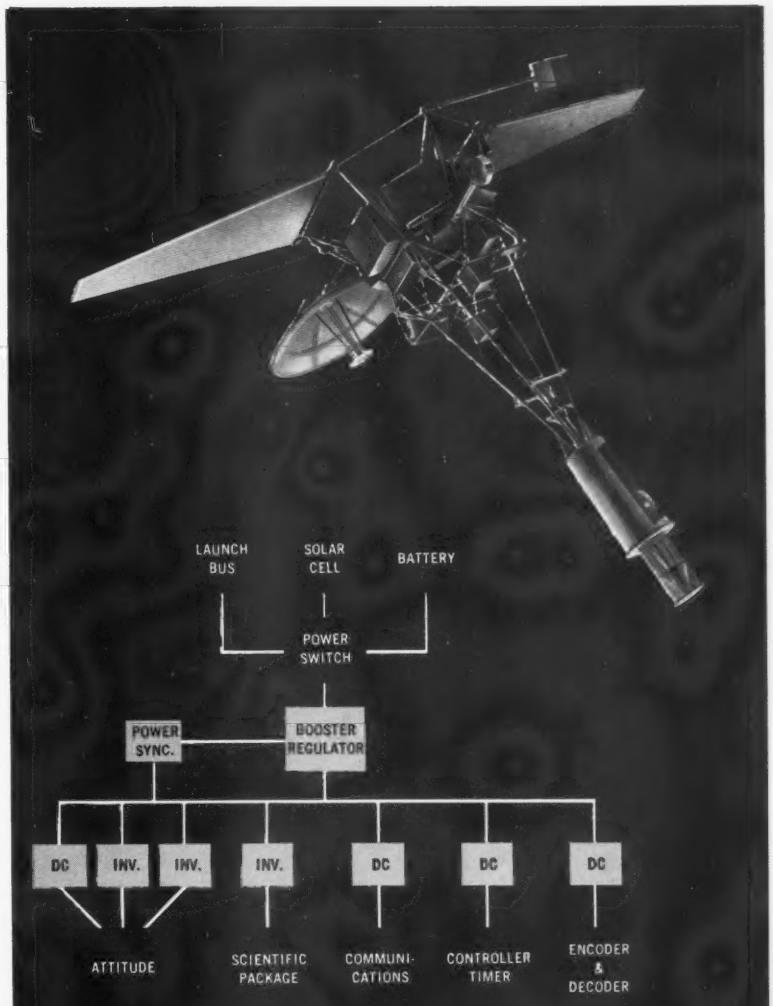
b. *Magnetic attitude control of the spin axis.* The torque produced by the interaction of an induced magnetic dipole in the satellite with the earth's magnetic field was determined to be the main cause of the Tiros I spin axis wandering from its predicted (space-stationary) position. For Tiros II, 250 turns of fine wire capable of carrying a variable current were incorporated in the satellite to provide a controllable magnetic dipole. By means of the predicted torques, it was hoped to provide some control of the satellite orientation and thus improve the observational conditions. This magnetic orientation coil has been activated several times with very satisfactory results.

c. *Lubricated ball bearings.* In precision instruments such as the IR radiometer, where the alignment of optical elements must be preserved and wear on the bearings must be minimized, ball bearings with conventional lubrication techniques are essential to gain the necessary low power drain, long life, and reliability. By proper design and careful fabrication, it has been possible to reduce the rate of oil flow out of the bearing assembly and to reduce the rate at which the lubricant volatilized under space condition of low pressure. As of the time of this writing, after 4 mo of operation in space, the bearing is still functioning properly, as attested by the transmission of meaningful data by the radiometer systems.

Serious Failures

The Tiros engineering subsystems did not all work flawlessly. There have been failures, the following being among the more serious:

a. The horizon-sensing attitude indicator subsystem of Tiros I did not produce the desired information. Satellite attitude had to be computed



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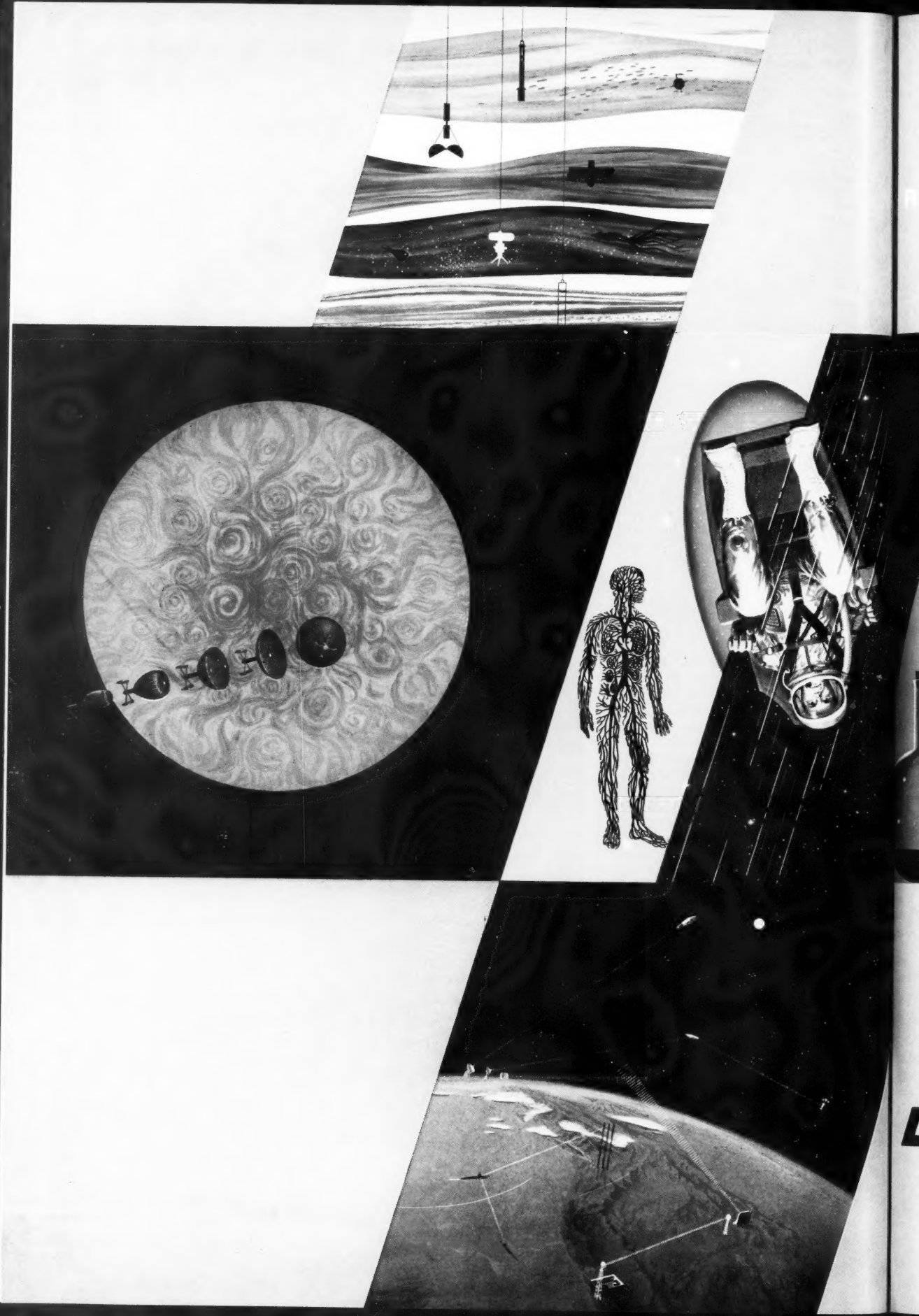

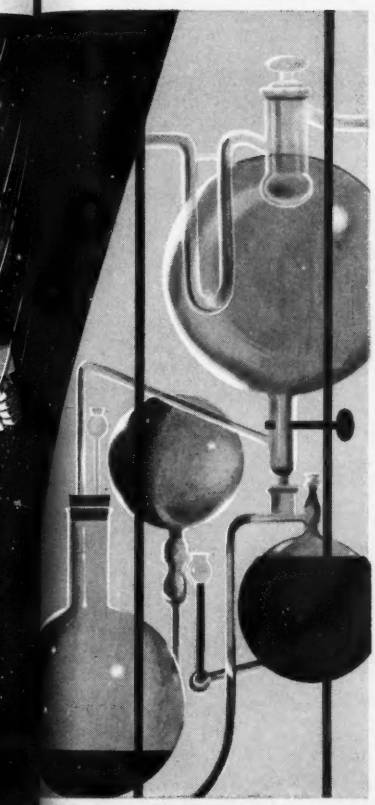

...is setting the pace in space for years ahead

Lockheed Missiles and Space Division's progress transcends even that of an era marked by phenomenal scientific growth. To an important degree, the Division's research and development activities are considered to be the basis of its success.

As systems manager for the Navy POLARIS Missile and the Air Force AGENA Satellite in the DISCOVERER and MIDAS programs, the Division is engaged in extensive research in many diverse engineering and scientific fields. Some highlights of current research and development activities include: Operations research and preliminary design; nuclear and space physics; physical electronics; chemistry; materials; mathematics; engineering mechanics; electronic communications and instrumentation; and computer research and development.

Research is a concept which holds many different meanings to those concerned with science and technology. At Lockheed, a distinction is made between the *nature* of the work and its *objectives*. Consequently, such terms as basic research, applied research, systems or operations analysis, engineering and development are used. A given individual might find that his personal inclination often leads him quite naturally from one type of research to another. Recognition of this desire is reflected in the scope of work conducted in the Research Branch at Lockheed Missiles and Space Division. Principal research activities are: Pure and applied research; advanced design; engineering analysis; electronic prototype development; and machine computation.

Organization is determined by the *technical field* rather than by the *type of research*. For example, a structural dynamicist, as a member of the Structures Department, may, on one occasion, work on future space vehicle configurations, at another time be associated with current projects such as the POLARIS or Satellite programs, or he may be engaged in basic research at the research laboratory. In each case, the individual has the opportunity to maintain as much or as little contact as he wishes with others in his field of interest.

Important staff positions at Lockheed's Research and Development Branch in Palo Alto are available. Those scientists and engineers with experience related to the above areas are invited to write to: Research and Development Staff, Dept. M-25B, 962 West El Camino Real, Sunnyvale, California. U. S. citizenship or existing Department of Defense industrial security clearance is required. All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin.

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primarily by the application of photogrammetric techniques to the photographs themselves. In Tiros II the highly successful IR radiation subsystem provides the required attitude information.

b. In Tiros I a relay became stuck in the command circuit, preventing the turning off of the TV transmitter. Continued transmitter operation drained the batteries and caused general failures. As a consequence, after orbit number 1302, about midnight June 29, 1960, it was decided to discontinue operations.

c. In Tiros II, a malfunction in the clock system for the remote-operation mode of the wide-angle camera caused the discontinuance of operations in that operational mode in order not to jeopardize the successfully operating subsystems. Direct wide-angle pictures, direct narrow-angle pictures, and remote narrow-angle pictures are still being taken at the time of this writing.

d. The Tiros II satellite occasionally responds to spurious and unexplained command signals.

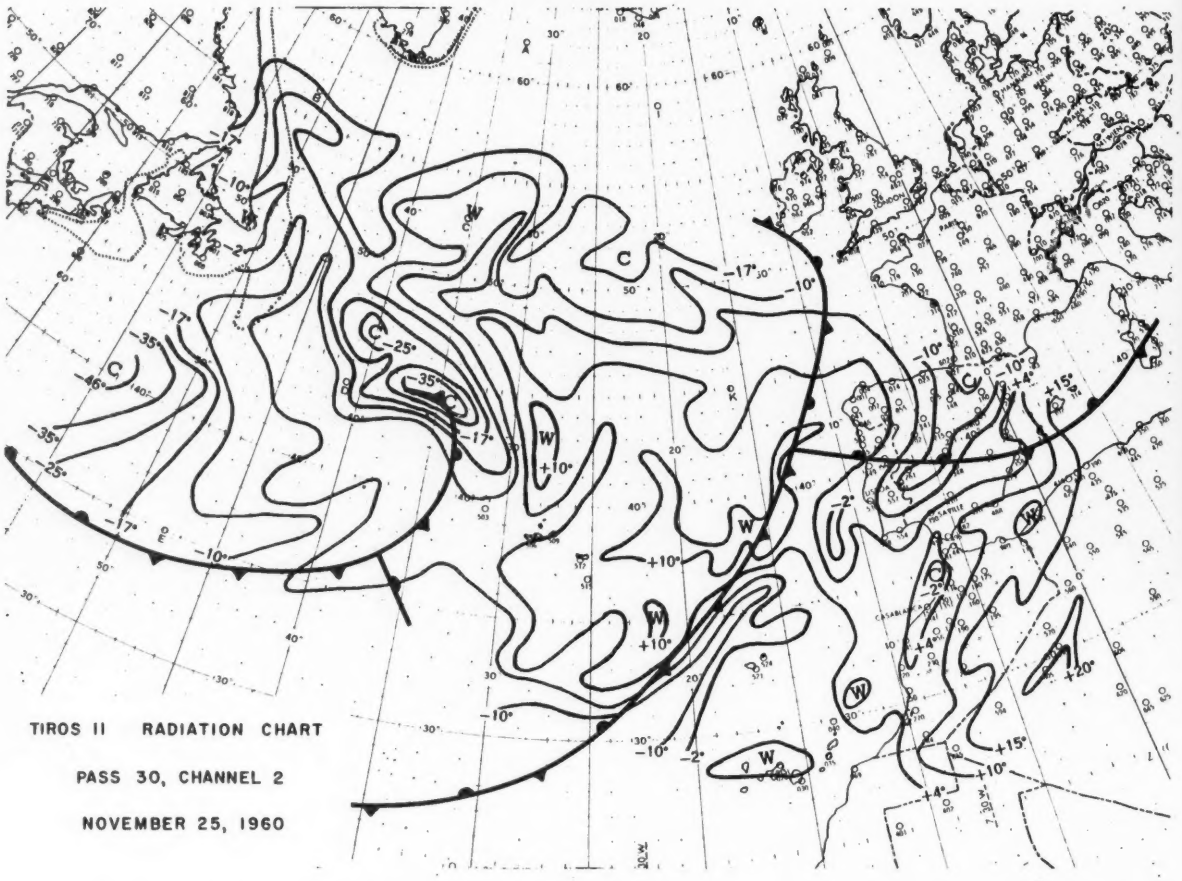
All in all, however, the satellite engineering systems worked very well and established without doubt the feasibility of meteorological satellites.

2. *Would the satellite measurements contain useful meteorological information?*

With the receipt of the very first pictures from Tiros I, it became apparent that the satellite system was photographing clouds, cloud formations, and cloud patterns. The meteorological research teams at the U.S. Weather Bureau, Air Force Cambridge Research Center, Naval Weather Research Facility and other institutions attacked the problem of interpreting the Tiros pictures in terms of weather information content. The first step was to compare the photographs with meteorological analyses from other available and more conventional observations, as reported by Winston and Tourville in the American Meteorological Society bulletin for March. The studies soon indicated excellent correspondence between the cloud formations and meteorological patterns, such as the following:

Low-pressure cyclonic storm systems (these appeared as spiral cloud formations in the satellite photographs), cold fronts, large areas of stratus cloudiness, unstable areas having cellular shaped clouds, local severe storms, jet stream, and mountain clouds. As a matter of fact, these

Tiros II Radiation Chart



Shown in this figure by Hanel and Wark are two weather frontal systems which lay in the Atlantic as Tiros II passed over and the temperatures derived from the satellite's radiation measurements. Associated with the one on the left is a region of marked low temperatures (indicated by "C" for cold) coming from the tops of the cold clouds usually found in the low-pressure center of the system. The frontal system to the right lies through a region of high temperatures (marked "W" for warm) off the coast of Spain. This would seem to indicate that this front is weak here and no longer has much cloudiness associated with it, so that the radiation is coming from the ocean or from the tops of low, and therefore warm, clouds. The higher-pressure region between the two frontal systems, in the mid-Atlantic, is a region of high temperature also, indicating that there is a lesser amount of cloudiness here.

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at work in Polaris program

The mission: to develop and manufacture the electronic digital computer that provides stabilization for the submarine periscope or radio-metric sextant; resolves celestial information in bearing and elevation order signals; provides data for the correction of the inertial navigator; and compensates for the effects of roll, pitch, heading, and mast flexure. **The means:** Burroughs Compútence. **The results:** precise launchings for Polaris. **Other USN missions-accomplished:** Polaris Fire Control Switchboards, aircraft carrier landing systems (through Burroughs Control Instrument Co.), and advanced digital airborne computers. **The message:** Be it by land, sea, air or space, Burroughs Compútence—ranging from basic research through production to field service—takes its bearings, goes straight for the goal. Burroughs–TM

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findings confirmed previous suggestions based on limited photographs from high-altitude rockets that nature was drawing a weather map by means of clouds.

By matching together overlapping photographs, it was possible to construct mosaics covering very large areas, such as the one of a family of several storms shown on page 28, drawn from V. J. Oliver, "Tiros Pictures of a Pacific Frontal Storm," *Weatherwise*, Oct. 1960. This mosaic covers almost 5000 mi, from the mid-Pacific to the central U.S. With it is shown the meteorological frontal analysis on which has been based the nephanalysis—the analysis of clouds as indicated in the photographs. The correspondence is excellent, but the detail afforded by the picture's cloud analysis is totally lacking in the broad brushstroke meteorological one.

Cloud Details Studied

Such detail is being studied to determine whether differences in the cloud patterns can yield information on the stage of development of a storm system or on its severity. In one such project, reported by R. Boucher at the AMS meeting in January, the cloud patterns have been studied in relation to the evolution of a "cyclone system" from its emergence as an "open wave" to the time of its "occlusion." If this study is successful, it may be possible to tell from the photographs alone the stage of development of a cyclone system.

The extraction of meteorological information from Tiros II IR data is proceeding at a much slower rate. This data is received in analog form, and for more rapid processing must be converted to digital representation and then married to the orbital data for position and look-angle reference. The data must then be plotted so as to be represented as a field. This process has been quite laborious, and only a limited amount of data has been analyzed. In general, however, results have been very satisfying. As expected, areas of low temperature have been associated with cloud zones (where the radiating surface is at higher and cooler altitudes) and areas of higher temperatures have been associated with cloud-free, high-pressure regions, as reported by Hanel and Wark at the AOS meeting in March, and indicated in one of their charts on page 66.

The answer to the question posed is again YES.

3. *Could the meteorological information contained in the satellite data be extracted and transmitted to the weather services in time to be of value in analysis and forecasting?*

It would have been significant enough had Tiros been successful only in providing new and detailed data about atmospheric processes. This would undoubtedly lead to a more thorough understanding of the weather and the factors that produce it. But a bonus was yet to come. In anticipation of the possible utilization of Tiros data for operational meteorological purposes, teams of civilian, military, and contracted meteorologists were at the data-acquisition stations to study the incoming data in "real time." Within 60 hr after Tiros I was launched, picture data less than 6 hr old was being interpreted and the analyses forwarded via facsimile transmission to the National Meteorological Center of the U.S. Weather Bureau at Suitland.

The chart on page 29, a copy of one of those transmissions, is of the system of the family of storms pictured on page 28. The cloudy areas are clearly depicted, as are the cloud bands themselves. The storm center south of the Aleutian Islands is clearly outlined by these cloud bands. Transmissions such as these were incorporated into the regular analyses and forecasts of the Weather Bureau; copies were also relayed to our air and naval services both in this country and overseas. The many reports which we have received, both from civilian and military field users, have been extremely enthusiastic about the usefulness of such data. Reports of the operational utilization of the Tiros II data, despite the degraded quality of the pictures from the wide-angle camera, have been even more enthusiastic. The operational weather services have indicated that these cloud analyses established, confirmed, or modified surface frontal positions, assisted in the briefing of pilots on accurate weather, were used in direct support of overwater deployment and aerial refueling of aircraft, gave direct support to an Antarctic re-supply mission, confirmed the position of a Pacific typhoon, and verified or amplified local analyses particularly over areas with few conventional reports, etc.

The quality of the IR radiation data from Tiros II has been excellent. However, as indicated, they have to be reduced and plotted on maps before they can be properly interpreted. From this point of view, until rapid processing techniques can be developed, the IR data are not as useful as the TV data for operational use.

Thus, the answer to the last question is again YES.

The operational utilization of Tiros data has captured the imagination of the weather services and has made them all the more impatient for the establishment of an operational meteorological satellite system to provide such data continuously and over the entire earth. Plans for the implementation of such a system are currently being developed by an interagency committee of experts.

What needs to be done now? The successful operation of the Tiros satellite system has brought into sharper focus the required direction toward which the meteorological satellite program should be heading. The areas which require development at this time are as follows:

a. *Satellite system improvement.* In particular, a larger spacecraft is required, to carry additional new and improved sensors. For global coverage, a polar orbit will be necessary and the spacecraft should be earth-oriented to increase earth-viewing time. These features are being planned for the next family of meteorological satellites—Nimbus.

b. *Data analysis.* The volume of data already acquired by the Tiros satellites and the volume of data to be expected from future meteorological satellites is enormous. The Weather Bureau is developing procedures for processing, storage, and retrieval of these data. Attempts are being made to encourage increasing numbers of investigators to study these data through aggressive contacts with the meteorological community in general and with university research groups in particular.

c. *Data transmission.* A critical part of the data-volume problem is transmitting the meteorological content of data to operational meteorologists in as near real-time as possible. This involves determination of the significant meteorological content of satellite output (of interest to the weather forecaster) and development of rapid transmission techniques to make this content available to the user in time for use. Satellite on-board analysis, ingenious techniques for data presentation, automatic-analysis instrumentation, improved transmission facilities, advanced communications relays—all are developments which are of current concern. ♦♦

Fourth Temperature Symposium Held

The Fourth Symposium on Temperature, Its Measurement and Control in Science and Industry, sponsored by NBS, AIP, and ISA (third symposium took place in 1954), was held recently at Veterans Memorial Building in Columbus, Ohio. Proceedings will be published by the Reinhold Publishing Co.

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tlas is the free world's first intercontinental ballistic mise; the first missile to travel more than 9,000 miles across the earth's surface; the only one to lift itself into orbit. Atlas marked the first use of swivel engines for directional control and it was the first to use airframe skins as fuel cells.

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You'll find most of the details on this and the following page, plus a convenient inquiry card. If the card has been removed, or if you wish to furnish or request more detailed information, write to Mr. R. M. Smith, Industrial Relations Administrator-Engineering, Mail Zone 130-90, Convair/Astronautics, 5661 Kearny Villa Road, San Diego 12, Calif. (If you live in the New York area, please contact Mr. J. J. Tannone, Jr., manager of our New York Placement Office, 1 Rockefeller Plaza, CIrcle 5-5034.)

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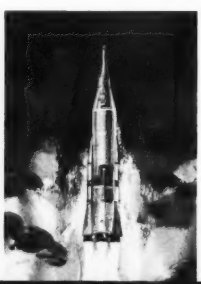


CONVAIR DIVISION OF GENERAL DYNAMICS

ARS news

Missile and Space Vehicle Testing Conference Highlights Future Operations

Test operations are headed for a new era of toughness and rigor in both space and defense programs, appeared to be the message of the ARS Missile and Space Vehicle Testing Conference held in the Biltmore Hotel, Los Angeles, Calif., March 13 to 16 under the auspices of the ARS Test Operations and Support Committee, chaired by B. L. Dorman, Aerojet-General Corp. vice-president for test operations.

Outstanding luncheon addresses pointed to goals of testing that will receive increasing emphasis as the complexity and scope of programs grow and push costs upward—such goals as providing data that can be used as the basis for design decisions, shortening the time it takes to check-out and launch a vehicle and payload, and producing practical hardware, qualified by tests under operational conditions.

At Monday's luncheon, Maj. Robert A. White of the Air Force, X-15 pilot and branch head at the AF Flight Test Center, Edwards AFB, Calif., reviewed results of the X-15 program, and particularly physiological tests on pilots. Significant conclusions, he said, have yet to be drawn from physiological data taken on six pilots in eight X-15 flights. He emphasized the need to correlate test techniques with hoped-for results.

Tuesday, William A. Fleming, assistant director for programs at NASA headquarters, tackled the whole concept of developing space vehicles. His position: "We must adopt an entirely new philosophy of how to design, manufacture, test and launch our vehicles." The aim of new work, he said, should be the development of vehicles and payloads that can be launched within *a week at the most* upon delivery at the launch site—rather than the six weeks that typically goes into a launch operation now. Automatic checkout equipment, he noted, will be necessary to reach this goal.

Wednesday, Vice-Admiral John T. Hayward, USN, deputy chief of naval operations for research and development, hit hard on the need to conduct

Chairmen for the conference—left to right, Jack Brown of Aerojet-General, assistant in program planning, Dale Carpenter of Rocketdyne, general chairman, and Bernie Dorman of Aerojet, program chairman—talk over the three days of technical sessions at the close of the meeting.

Luncheon speakers, left to right, Maj. Robert A. White of the Air Force, X-15 pilot and branch head at the AF Flight Test Center at Edwards AFB, William A. Fleming, assistant director for programs at NASA headquarters, and Vice-Adm. John T. Hayward, USN, deputy chief of naval operations for research and development, really put attending engineers on their toes with well-chosen, forward-looking remarks on important aspects of test planning.

George Mueller, vice-president of STL and associate director of its Research and Development Div., presents his paper, "Semi-Automatic Checkout of Spacecraft," in the unclassified session on space-vehicle instrumentation, chaired by Frank Lehan of Space Electronics Corp. and Joseph Koukol of JPL.

testing under *operational* conditions. He reviewed the functions of his command and the Navy's Operational Development Force in evaluating hardware and testing techniques.

The Conference drew some 700 attendees. Most sessions were well attended, particularly so the three classified ones on static testing, flight testing, and program experiences. The field trips on Thursday after the sessions, one to Edwards and the other to Vandenberg, drew over a hundred each to view new and important facilities in the space program.

The meeting itself went very smoothly under the direction of General Chairman Dale Carpenter of Rocketdyne, Program Chairman B. L. Dorman of Aerojet, and his assistant, Jack Brown, of Aerojet. Papers from the meeting are available as preprints from ARS Headquarters, 500 5th Ave., New York 36, N. Y., Attention: Meetings Dept.

SECTION NEWS

Antelope Valley: In February, the Section met jointly with the local sections of IAS and the Society of Experimental Test Pilots. Approximately 156 attended the dinner meeting to hear this panel—**L. P. Greene** of North American, **A. H. Flax** of the Air Force, **W. T. Hamilton** of Boeing, **R. R. Heppe** of Lockheed Aircraft, **F. W. Kolk** of American Airlines, and **C. A. Lau** of Chance Vought—discuss problems and approaches in aircraft design in the 1970 to 1980 period. The meeting was interesting and informative.

—Leslie O. Harrington

Central Texas: In February, the Section held a joint dinner meeting with the Texas Society of Professional Engineers as a feature of Engineers Week. Approximately 75 persons attended, including 20 ARS members. **H. R. Drew** of Fort Worth, Tex., executive vice-president of the Texas Atomic Energy Research Foundation, addressed the meeting on the fusion process as a source of energy; and a film was shown entitled "Reaching for the Stars."

—C. R. Rowe

Chicago: An enthusiastic group of 30 rocketeers gathered in the Chicago Room of the Como Inn for the Section's triple-feature February meeting. Featured speaker of the evening was ARS Director **Bob Gross,** who addressed the members and guests on "Plasmas and Space." Preceding the formal presentation was an illustrated description by Section vice-president Peter Lagus of the Lane (High School) Amateur Rocket Society's activities, and a screeching demonstration of the Edroc by Youth Activities Chairman George Chamlin. A lively discussion of the hopes and hazards of amateur rocketry concluded the evening.

—C. C. Miesse

Columbus: In a March meeting, held at Battelle Memorial Institute, a short movie, "The Big Bounce (Echo I)," was shown, and guest speaker **John H. Shaw,** associate professor in the department of physics and astronomy at Ohio State Univ., discussed the composition and properties of the upper atmosphere (above 50 mi) and the effect of the sun's radiation upon them. Also considered were solar flares, interplanetary gas, cosmic dust, the radiation belts, the ionosphere, the ozone layer, and aurorae. Dr. Shaw showed some very unusual color slides of aurorae and other phenomena.

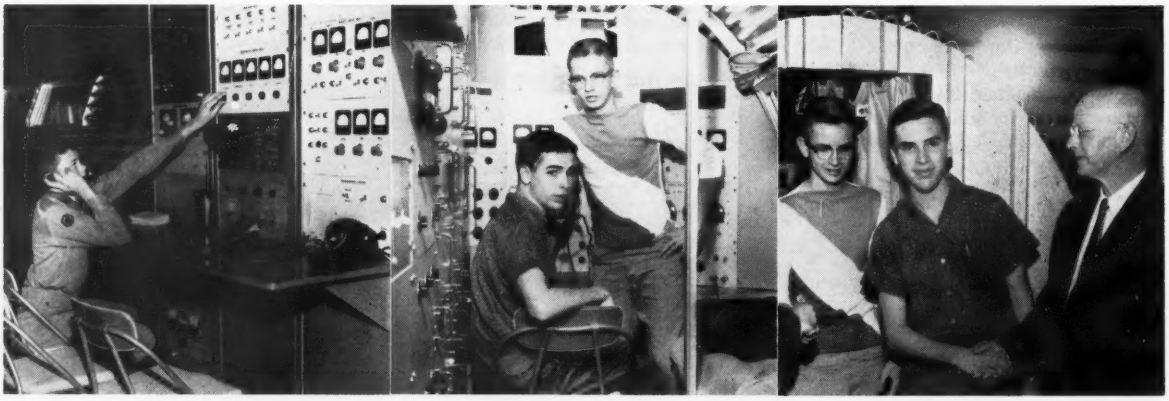
—James A. Laughrey

Holloman: In a February dinner meeting, held at the Holloman Officers Club, guest speaker **Brig. Gen. John Shinkle,** commanding officer of the White Sands Missile Range, discussed "Missile Testing at White Sands Missile Range." General Shinkle pointed out that the Army Ordnance group has two primary missions at WSMR.

The first is to operate, with the aid of the other services, the integrated range. This means providing the means to assure acquisition of data required by the user. Instrumentation includes Cinetheolite cameras (at least 75), telescopes, very high speed cameras, ballistic cameras, Dovac (electronic space-position devices), and several types of radar.

The second mission is the responsibility for Army testing. The types of tests include research and development (contractor support), engineering, user or service tests, proof tests, industrial engineering tests, and surveillance testing. There are approximately 1600 people involved in the Army testing mission, and 2000 in the

Spaceship Simulator on the Mars Scene



Gregory Knight, at the left, contacts the Project Marsflight spaceship simulator and its passengers, center, astronauts Mark Depp and Tommy Marks (with glasses), during a 24-hr voyage into the unknown. At the right, R. A. Ibison of Electronic Communications Inc., who designed the simulator for Science Center of St. Petersburg (Fla.) Inc., a nonprofit educational institution, congratulates the explorers on a safe return. The Marsflight simulator—which contains such advanced features as provision for inflight maintenance, space-to-ground communications, a mapping-radar navigational simulator, and a full set of programmed flight-condition controls—was constructed in less than five weeks for only $500. Dr. Ibison has proposed the vehicle as the basis for an integrated program in astronautics for student groups.

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actual operation of the range itself.

General Shinkle concluded his talk with a film showing milestones in the testing of the family of Army missiles.

—**Harry H. Clayton**

Kansas City: This ARS Section acted as host to the local sections of the IRE, IAS, AIEE and the ACS at a chuckwagon dinner in March. Forty-three members of the five societies dined together; five ARS members each brought one or more personal guests as part of a vigorous Membership Committee effort. Seventy-eight persons attended the post-dinner illustrated talk on "Electric Space Propulsion System" given by guest speaker **Mark L. Ghai,** manager of the GE Electric Propulsion Laboratories in Cincinnati, Ohio. His talk was followed by a lively question and answer period.

During a brief business meeting, the Section formally recognized the conference of an Award of Merit from the ARS National Office to **Alan R. Pittaway,** our first president. Buell W. Beadle of Midwest Research Institute conducted the ceremony. In addition, the Program Committee revealed a robust 1961 program of nationally recognized speakers, trips to nearby space-oriented facilities, and social events.

Palm Beach: In a March meeting, 78 members and guests heard guest speaker **John Larsen** of the Connecticut Aircraft Nuclear Engine Laboratory (Canel) discuss "Aircraft Nuclear Propulsion"—engine and reactor design, problems of a system, etc.

Our next meeting, on May 31, will have **Dorian Shainan,** one of the top reliability experts in the country, discussing "The Role of Reliability in Aerospace Technology."

—**Harold J. Tiedemann**

Princeton: A small but loyal following of 30 people attended the March meeting on one of the wettest nights of the year to hear guest speaker **Robert Danielson** of Princeton Univ. discuss "Project Stratoscope, Present and Future" (see page 38). Some of the scientific aspects which Stratoscope will look into include the study of the atmosphere and surface of Venus, Jupiter, Mars, Saturn's rings, and other targets. Of particular interest will be the study of star formation, planets of other stars, and some distant stars which presently are obscured by the background glow when viewed from the ground. A spirited question and answer period followed.

—**H. M. Gurin**

Syracuse: In March, **Julius M. Werner,** associate professor of mechanical engineering at Syracuse Univ., addressed the membership at the official charter-presentation meeting. **Len Barker,** president of the sponsoring ARS Central New York Section, did the honors and made the charter presentation to Carl Petroff, Syracuse graduate student and president of the new chapter.

In his address, "Electric and Exotic Space Propulsion Systems," Dr. Werner pointed out the advantages of plasma and ion engines in space missions. He also paid tribute to the pioneers of rocketry in Europe and the United States as he traced the growth of technical knowledge.

—**C. E. Babcock**

Wichita: Approximately 40 members and guests convened in the Univ. of Wichita Campus Activity Center in March to listen to a discussion of the "History, Status and Capability of the Pacific Missile Range" by Lt. Cmdr. **George Hamilton,** USN. With the aid of slides, Cmdr. Hamilton, Briefing Officer at the Pacific Missile Range, reviewed the history of missile-test-range requirements in this country, range management, and future applications to the space program, including capabilities and limitations at the Air Force-managed facility at Cape Canaveral and the Army-managed facility at White Sands. He then discussed the development of the Pacific range to the current capability concentrated at Point Arguello and the relationship of the activity there to that at Vandenberg AFB, emphasizing that the Pacific Missile Range is a research and development facility, while Vandenberg is the first SAC-ICBM base and is being used to train crews for additional bases.

—**C. M. Long**

STUDENT CHAPTERS

Univ. of Michigan: At the Chapter's first meeting of the new semester, in February, **Robert M. Howe,** professor of aeronautical engineering at the University, spoke to us on "Simulation of Orbital Flight Using an Analog Computer."

The March meeting had as guest speaker **Ray L. Newburn,** a senior

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scientist at the Jet Propulsion Laboratory, who discussed "Venus—Astronautical Prize and Scientific Mystery."

—**Judith M. Forde**

Univ. of Washington: At the February meeting, 54 members and guests heard guest speaker **George Hoover** of Aerojet-General's Solid Rocket Plant at Sacramento, Calif., discuss the "State of the Art in Solid Propellant Rockets at Aerojet." In addition to this very interesting talk, he showed two excellent films, one on Polaris and the other on Minuteman.

—**Patricia L. Blake**

TECHNICAL COMMITTEES

Electromagnetic and electrothermal propulsion warrant attention in specialists conferences, was the informal opinion of the ARS Electric Propulsion Committee, headed by Ernst Stuhlinger of Marshall SFC, as it held its first meeting of the year recently to plan contributions to upcoming meetings, such as the Space-Nuclear Conference taking place in Gatlinburg, Tenn., May 3–5; the joint IAS-ARS Semi-Annual Meeting scheduled for June 13–16 in Los Angeles; the Gas Dynamics Symposium at Northwestern on Aug. 23–25; the IAF Congress in Washington, D.C., the first week in October; and the SPACE FLIGHT REPORT TO THE NATION to be held in New York's Coliseum Oct. 9–15. The members of the Committee will constitute a panel to discuss the status of electrostatic propulsion at the SFRN.

A history of liquid rocketry in America, dramatized by its living representatives, such as Mrs. Robert Goddard, is the ARS Liquid Rocket Committee's project for the SFRN. It is the Committee's plan to have its SFRN session filmed as a document for wide distribution. The Committee is also working on a classified panel to discuss interactions of rocket engines and vehicle structures for the joint IAS-ARS Semi-Annual Meeting in June.

Space simulation and training in the holding facility, dangers of meteoroids and radiation, weightlessness and artificial gravity, spacesuit design, and other topics will be brought to the fore in the two sessions planned by the ARS Human Factors and Bioastronautics Committee for the SPACE FLIGHT REPORT TO THE NATION. The Committee plans to make use of many documentary film clips to highlight its presentations open to the public.

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1961 ARS Meeting Schedule

Date	Meeting	Location	Abstract Deadline
May 3–5	Space-Nuclear Conference	Gatlinburg, Tenn.	Past
May 22–24	National Telemetering Conference	Chicago, Ill.	Past
June 13–16	National IAS-ARS Joint Meeting	Los Angeles, Calif.	Past
Aug. 7–9	Guidance and Control Conference	Palo Alto, Calif.	Past
Aug. 16–18	International Hypersonics Conference	Cambridge, Mass.	Past
Aug. 23–25	Biennial Gas Dynamics Symposium	Evanston, Ill.	Past
Oct. 2–7	XIIth International Astronautical Congress	Washington, D.C.	May 1
Oct 9–15	ARS SPACE FLIGHT REPORT TO THE NATION	New York, N.Y.	Past

Send all abstracts to Meetings Manager, ARS, 500 Fifth Ave., New York 36, N.Y.

CORPORATE MEMBERS

Aerojet-General is constructing a $\$1^1/_4$ million facility at its Azusa Plant to test and manufacture infrared subsystems for the AF Midas satellite, and also has signed a licensing and technical assistance agreement with Society Europeenne De Teleguidage (SETEL), Paris, for Hawk motors production. In connection with a $1 million expansion program, AG Nucleonics has purchased 474 acres adjoining its San Ramon site . . . **Atlantic Research** has acquired about 15% ownership of Nuclear Science and Engineering Corp., Pittsburgh, Pa., nuclear engineering firm . . . The Systems Div of **Beckman Instruments** has opened a new field engineering office in Albuquerque, N.M. . . . **Bulova Watch Co.** has been awarded the 1960 Miniaturization Award for its Accutron electronic timepiece.

Callery Chemical Co. has moved its Encino (Calif.) labs and offices to 15537 Lanark St., Van Nuys, Calif. . . . **Chance Vought** and Ling-Temco Electronics have approved in principle a merger plan . . . **Eastman Kodak** has announced it will manufacture and sell magnetic recording tape beginning later this year . . . **Electro-Optical Systems** has added a 16,000 sq-ft lab building to its present R&D facilities at Pasadena . . . **GE** plans a $750,000 expansion in its phenolic molding compound plant at Pittsfield, Mass., increasing capacity some 30% . . . Kearfott Div. of **General Precision** has formed an Advanced Products Dept. within its Gyrodynamics Branch . . . **Hughes Aircraft's** semiconductor division has established a new department for packaged assembly service.

ITT has purchased Jennings Radio Mfg. Corp., San Jose, Calif., developer and manufacturer of high-power vacuum capacitors and switches. An Avionics Service Dept. has been formed at ITT Federal Laboratories . . . **Walter Kidde & Co.** has formed Kidde Electronics Laboratories, combining the companies electronics R&D activities thereby . . . **Linde Co.'s** new liquid oxygen-nitrogen plant, Neosho, Mo., has gone on stream with a capacity of 140 tons per day . . . For outstanding achievement in space science, **Lockheed** has been awarded the Hoyt S. Vandenberg Trophy for 1960 by the Arnold Air Society. In addition, the Missiles and Space Div. has been named the winner of the Dr. Robert Hutchings Goddard Memorial Trophy for 1960 for its accomplishments in the Polaris and Discoverer programs.

The **Martin Co.** has established a new department, Nuclear Chemistry Dept., to integrate all of its activities at Quehanna, Pa. . . . Autonetics Div. of **North American Aviation** recently broke ground for its $2 million research center in advanced microelectronics . . . **Northrop Corp.** started construction last month of a new $1.7 million engineering and administration center at Anaheim, Calif. . . . **Wyman-Gordon** has formed a new Product and Sales Development group.

Call for Papers

Papers on **Nuclear Propulsion Test Facilities** and **Nuclear Rocket Mission Studies,** for presentation at two unclassified sessions of the ARS SPACE FLIGHT REPORT TO THE NATION (Annual Meeting) scheduled for Oct. 9–15 this year, are being solicited by the ARS Nuclear Propulsion Committee. Authors who wish to be considered should **send abstracts** of papers to **R. W. Bussard,** Los Alamos Scientific Laboratory, P. O. Box 1663, Los Alamos, N. M., **by May 15, this month.**

Two More Companies Become Corporate Members

ARO, Inc., and Straza Industries have joined the honor roll of American Rocket Society corporate members participating in Society activities. The companies, their areas of activity, and those named to represent them are as follows:

ARO, Inc., a subsidiary of Sverdrup & Parcel, Inc., Arnold Air Force Station, Tenn., manages and operates and maintains the AF's Arnold Center near Tullahoma, conducting all test programs and developing new equipment and test techniques for the Center's $325 million advanced wind tunnels and high-altitude rocket test cells. Named to represent the company in ARS are L. J. Sverdrup, president; B. H. Goethert, director of engineering; R. M. Williams; managing director; H. E. Gardenier, manager, Rocket Projects Branch-Rocket Test Facility; and H. M. Cook, manager, Plant Operations Branch-Rocket Test Facility.

Straza Industries, El Cajon, Calif., produces mass spectroscopy, solid state devices, and circuitry and solid rocket nozzles, rocket combustion chamber tubing and components for liquid engines. Representing the company are Lesle W. Russell, vice-president, manufacturing; Myrl P. Bratton, vice-president, contracts; Daryl G. Mitton, vice-president, Chemical Milling Div.; Herman W. Volberg, manager, Electronics Div.; and Larry E. Hemmel, regional representative. ♦♦

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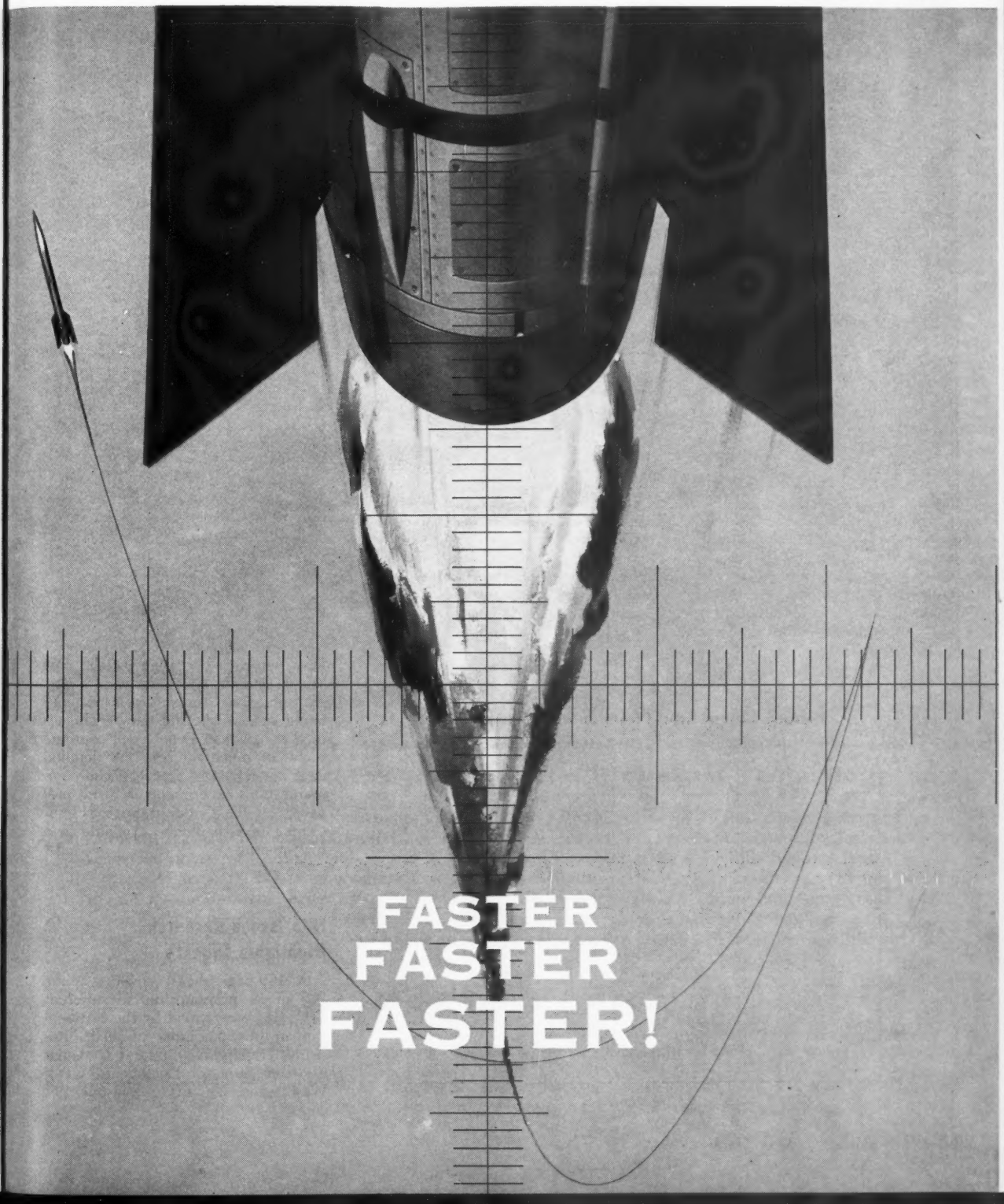


Project Echo Results

(CONTINUED FROM PAGE 33)

systems could handle such letters in a matter of seconds.

These were some of the more dramatic results. Of course, considerable technical experimentation took place. All of the characteristics of the transmitted and received signals were recorded for analysis. Many modulation techniques were used. These data are still currently being reviewed, but the analysis to date has indicated the following:

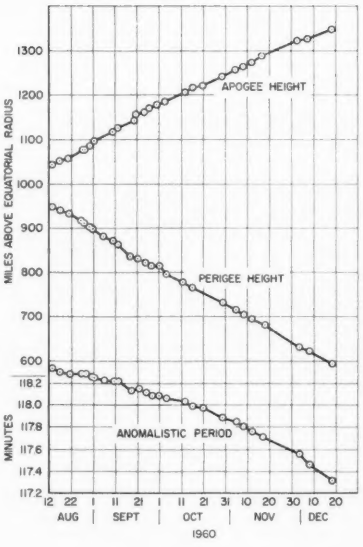
1. No deviations from propagation theory were observed.

2. Returned signal strength from Echo I was within 1 db of theoretical during the pressurized life of the satellite (approximately 14 days) and little scintillation was observed in this period. Upon coming out of the 10th (Aug. 25, 1960) eclipse with the earth, the average returned signal dropped off approximately 3 db, indicating an average reflective cross-section equivalent to that of a sphere about 75 ft in diam. The scintillation since then has been increasing somewhat, indicating a fluctuation in shape or a wrinkling of the satellite surface. The period of such fades seems to be independent of frequency and therefore the fading is caused by a geometric variation in the satellite shape, and is not the result of interference patterns in the reflected waves.

The feasibility of using a passive satellite as a communications reflector has been established. The fact that Echo I did not completely collapse upon loss of its internal pressurization material has indicated that the thin wall structure is almost structurally sound enough to withstand the space environment, and that only a nominal increase in rigidity will provide long-life structures.

In addition to the communications experiments, Echo I has contributed significantly to our understanding of the space environment and the causes of orbital perturbations. Because of its large size and small relative weight, Echo I is extremely sensitive to the effect of atmospheric density and solar radiation pressure. Measurements of atmospheric density at the satellite altitudes are continuing, and are indicating large variations and time-dependence. The position of the sun and its heating effect on the atmosphere are being observed and studied in great detail. A mean density of 10^{-18} grams/cm^3 was measured at an altitude of 1500 km.

Apogee, Perigee, and Period of Echo I



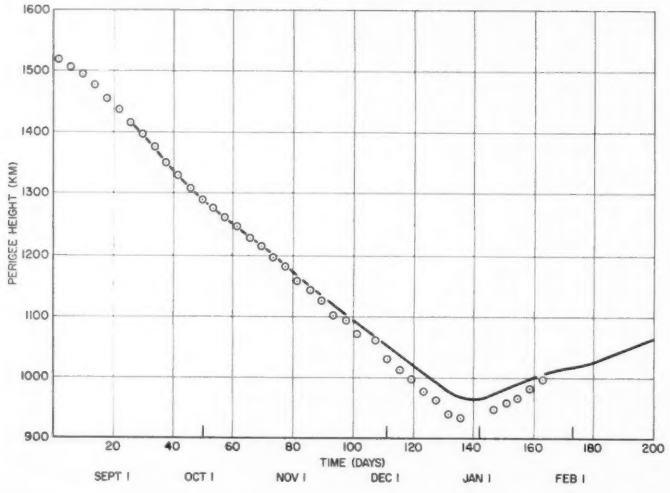
On Nov. 12 and Dec. 5, 1960, severe solar disturbances occurred, and a corresponding change in the rate of change of Echo I's orbital period was observed. This, too, can be related to an increase in atmospheric density at an orbital altitude caused by the solar flares.

Dramatic Perturbation

The most dramatic perturbation on the Echo I orbit is caused by solar radiation pressure. The effect is one of shifting the orbit away from the sun. Initially the orbit was nearly circular, with an apogee of 1049 mi and a perigee of 945 mi. As a result of solar radiation pressure, apogee increased and perigee decreased as indicated in the graph top left. This process continued until the end of 1960, when perigee reached a minimum of approximately 930 km. The orientation of the orbit with respect to the sun is now such that the orbit is being pushed back toward its initial position with respect to the earth, and perigee is increasing. The graph bottom left indicates this change in perigee with time and the close agreement of theory (solid line). This process is cyclic with a period of about a year. It is now predicted that Echo I will remain in orbit for at least another year.

Although Echo I has degraded somewhat in shape, and will continue to do so, it is still a useful radiowave reflector. Periodic measurements are being made of its radar cross-section. The beacon transmitters on Echo I have not been operating for the past several months, but the Smithsonian Astrophysical Observatory is accumulating optical tracking data. The orbital behavior of Echo I will continue to be of much interest. A detailed final report on the Project Echo communications experiments is being prepared by the Goddard Space Flight Center, and should be available in a few months. ♦♦

Perigee Shift of Echo I from Solar Pressure



NBS Issues Research Highlights Digest

A 189-page digest covering some 225 of its programs in 18 different fields has been issued by the National Bureau of Standards. Called "Research Highlights—1960," it is available from Supt. of Documents, GPO, Washington 25, D.C., for 65¢ per copy.

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Deep-Space Communications

(CONTINUED FROM PAGE 26)

other hand, the atomic battery has a finite half-life. Atomic-battery development is just beginning at this date; present estimates may change considerably. At present, approximately 1500 whr/kg are available; the watt-hours must be used over the half-life of $3^1/_2$ yr. Thus 900 kg of batteries would be required to supply 50 w for 3 yr. A more radical technique using a strontium "hot brick" in a heat engine would have a power capability of 2 kw/kg with a half-life of 25 yr. However, handling problems would be severe. A considerable amount of lead shielding might be required.

Another newcomer is the so-called energy cell. Hydrogen and oxygen are stored and then combined at almost any rate to supply power on demand. Like other chemical storage, this cell supplies total energy in watt-hours. The present weight factor is 2000 whr/kg.

All these power sources supply power at dc. None supply radio frequency directly. The conversion from dc to radio energy is not notably efficient: 10% is typical, 30% is outstanding. Less than perfect efficiency has two consequences: Added weight for the power-conversion equipment and added weight for heat dissipation. Heat dissipation in a vacuum is not as simple as in the atmosphere where air cooling is available. All excess heat must be radiated. Considerable area may be required to dissipate the heat created by inefficient power conversion.

Choosing Frequency

The transmitting frequency should be chosen to give the maximum range of communications with a minimum weight required in the vehicle. This maximum range was given by Equation (5), Part 1, April *Astronautics:* $d = \sqrt{P_t A_t G_r / 4\pi k T \Delta f}$. This equation was derived assuming that the vehicle antenna was area-limited and the ground antenna was gain-limited. Under these conditions the threshold reception range contains no explicit terms in transmission frequency. Two conclusions may be drawn. First, a relatively broad range of frequencies may be usable for space communications. Second, the final choice of frequency will probably depend more on the state of the art in electronics and space vehicles and on the frequency characteristics of the interference than on the more obvious terms of Equation (5).

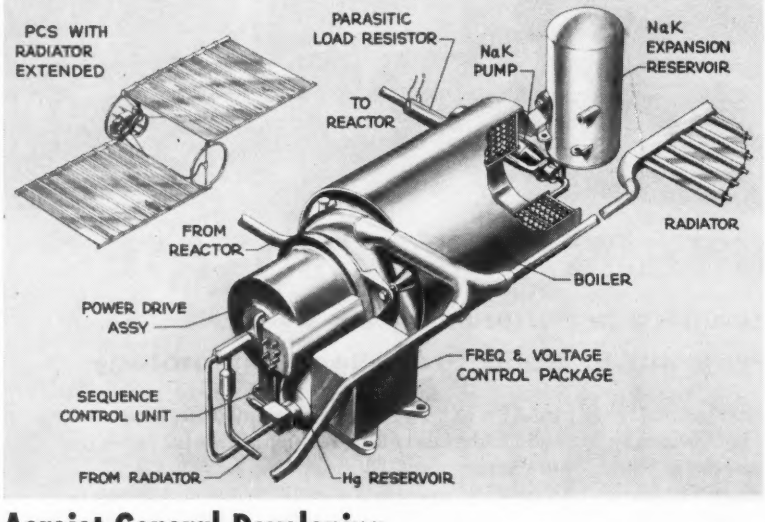
The changes in practical electronics since 1954 are noteworthy. An efficient transmitter at 1000 mc has been used in the lunar probes; transistor techniques are used in all but the last stage, which the state of the art will shortly transistorize as well. Extremely low noise figure receivers of the solid-state maser variety make possible efficient reception to well above 8000 mc. Solar-energy converters are being developed which will make possible transmitters with 10- to 100-w capacity at ultrahigh frequencies and microwave frequencies. These new devices are pushing the state of the art at present. By the time interplanetary vehicles are launched, the devices will be nearly commercial.

Another development of significance in space communications is the technique of phaselocked receivers for extreme sensitivity and narrow-bandwidth reception at frequencies from 100 to 20,000 mc. By following the phase of the incoming signal very accurately, it is possible to cancel out doppler shifts and most oscillator instabilities. The bandwidth necessary to follow the phase is far less than the doppler shifts involved, and consequently extremely narrow bandwidth (Δf) reception is possible. For example, a receiver bandwidth of 20 cps has been used to follow doppler shifts of 10 kc at a carrier frequency of 1000 mc. It should thus be concluded that the state of the art in electronics will not long be a significant limitation to the choice of frequencies for an earth-space-earth system.

The Temperature Factor

A more serious factor in the selection of frequency is the dependence of the system temperature, T_s, on frequency. Frequencies much below 400 mc would result in system temperatures significantly greater than those achievable using the advanced receiving systems (30 K) aimed more than 10 deg above the horizon and using frequencies above 1000 mc.

A second factor which favors the frequencies above 1000 mc is the high cost of large ground antennas. The cost of parabolic antennas is roughly proportional to the 2.7 power of the diameter. Therefore, if a 30-m-diam antenna costs about $1,000,000, a 180-m antenna will cost about $100,000,000—a very large figure, indeed. From Equation (5), it can be seen that the critical parameter for the ground receiving antenna is its gain, not its area. Consequently, a small but accurately surfaced antenna can



Aerojet-General Developing Snap-8 Power Conversion for NASA

The illustration shows the power-conversion system being developed for Snap-8 by Aerojet-General Power/Equipment and Nucleonics groups under an $8.23-million contract to NASA. In conjunction with the Snap-8 reactor, under development for the AEC by Atomics International, the system will turn out 30 kw of electrical power for a minimum of a year in space. Snap-8 should begin to phase into space operations within five years.

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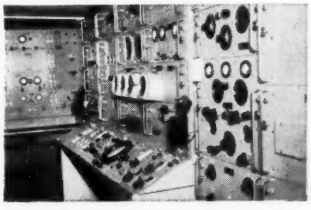

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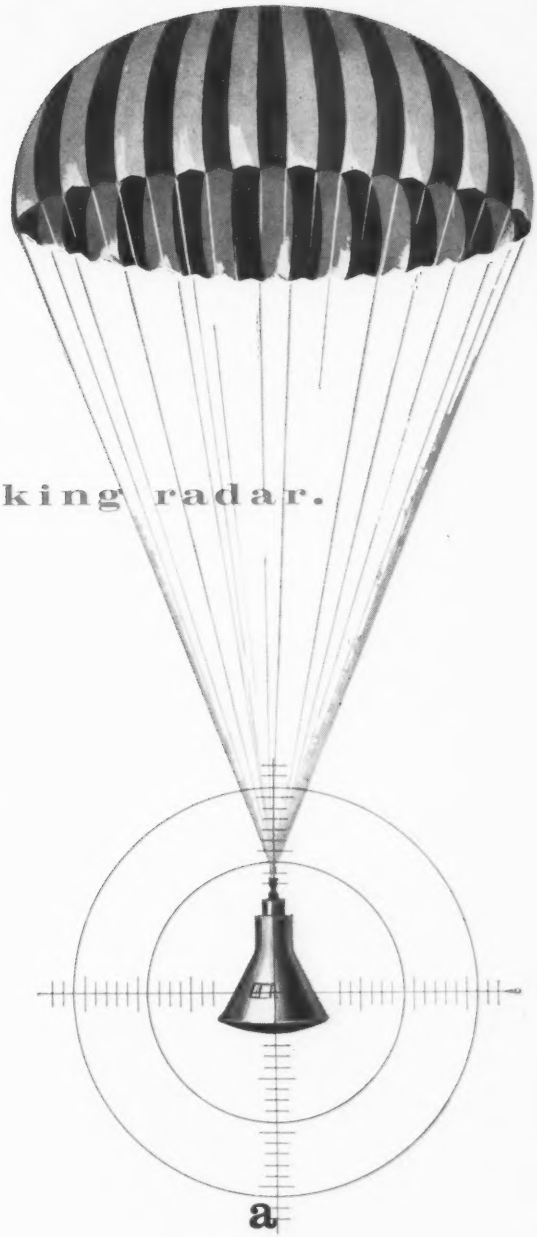

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equal or exceed the performance of a larger but rough-surfaced antenna, provided the best transmitting frequency is selected for each antenna. Because the smaller antenna requires a higher frequency than the larger antenna for best operation, the antenna cost factor strongly favors the higher frequencies.

Based only on the foregoing discussion, the frequency choice would seem to be: The higher the frequency the better. Two factors combine to limit this trend. The first is a sharp increase in atmospheric noise and attenuation above 10,000 mc due to the presence of water vapor in our atmosphere. The second is the loss of efficiency in using the vehicle antenna area due to surface irregularities. The loss of efficiency occurs when the irregularities are greater than about 5% of a wavelength.

For all of the above reasons, it can be concluded that the frequency choice for communications to the earth from attitude-controlled spacecraft using directive antennas will be greater than 1000 mc and less than 10,000 mc. The resultant ground antenna diameters will be 80 m or less.

System Design

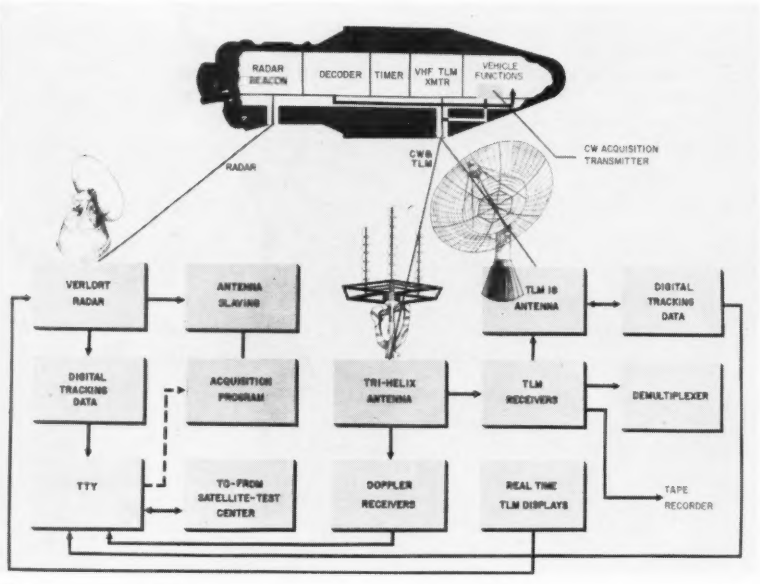
The illustrative designs given in the table on page 26 are by no means the only ones which could be made to work, nor are they the exact designs which may be built, but they are sufficiently good that they can be used for studying the effect of parameter variations.

Lunar orbiter with TV. Real-time television can be sent from the moon with surprisingly little difficulty. In this system, the vehicle antenna is sufficiently broad in beamwidth to illuminate the whole earth (hence the vehicle antenna is not required to track a moving ground station) and the ground antenna is sufficiently broad in beamwidth to cover the circling orbiter while aiming the beam at the center of the moon's face (permitting a very simple antenna drive system needing information only from an almanac). About 10 frames per second could be transmitted at an acceptable signal-to-noise ratio. Because the television of the moon is a sufficiently unique problem, a special modulation system might be provided, using more efficient information coding (FM, PCM, digital telemetry, etc.). Most coding techniques achieve their greatest utility when used with signal-to-noise ratios of about 10 db. Applied to the lunar orbiter, coding bandwidths of 100 mc could be used if desired.

Lunar lander with TV. The surface exploration of the moon by instruments can be enormously more effective if an observer on the earth can watch the operation using a television camera mounted on a lunar automobile. The weight and power limitations on such automobiles, and the difficulties of keeping the automobile antenna pointed accurately at the earth, make it worthwhile to reduce the lunar vehicle capability and to increase the earth ground capability by increasing ground antenna gain. (Ground tracking is not as severe a problem for the automobile as for the orbiter.) As noted in the discussion of lunar temperatures in Part 1, the increased gain of the ground antenna also results in somewhat increased system temperature.

Mars orbiter with facsimile. Although the minimum distance between the earth and Mars is only about 80-million km, the communication distance to an orbiter of Mars is considerably greater for two reasons: Efficient trajectories do not result in arrival at Mars when Mars is at a minimum distance, and it is desired to keep contact for at least one Martian year. The numerical values of the remaining parameters represent no particularly remarkable state of the art, with the possible exception of the vehicle's antenna beamwidth.

In this design, the Mars orbiter must keep its antenna pointed at the distant earth to within a fraction of a degree, a reasonable but not simple task for a space-vehicle attitude-control system. If this task proves too difficult to perform on early flights, the probable tradeoff would be to reduce the antenna area, to increase the vehicle antenna beamwidth as a consequence, and to accept the reduced video bandwidth as a result. An alternate, but much more expensive, tradeoff would be to use a lower frequency of trans-



Discoverer Program's Communications and Control System

The diagram shows the first unclassified picture of the Discoverer program's communications and control system, designed and put into operation by Philco's Western Development Laboratories under subcontract to Lockheed Missiles and Space Div., prime contractor to the Air Force for Discoverer. A combination of orbital-prediction techniques and this system allows microsecond-precision surveillance of a Discoverer space vehicle, and the kind of mid-air recoveries made of the vehicle's re-entry capsule last fall in the Pacific. Major contributors to the system include ACF Electronic Div.—radar beacon; Beckman Instruments—time-display equipment; Electronic Engineering Co.—timing systems; Milgo Electronic Corp.—data systems; Motorola—Doppler receiver; Radiation Inc.—telemetry and data antenna; and Reeves Instrument—Verlort radar.

Nowhere is this closeness more apparent than at Lockheed. Here, with each passing day, new technological advances help bring nearer the exploration of Mars, the Moon and Venus.

As the time grows shorter, the pace grows faster. New designs in Spacecraft and Aircraft are rapidly being developed —and the number continues to mount. Included are: Missiles; satellites; hypersonic and supersonic aircraft; V/STOL; and manned spacecraft.

For Lockheed, this accelerated program creates pressing need for additional Scientists and Engineers. For those who qualify, it spells unprecedented opportunity. Notable among current openings are: Aerodynamics engineers; thermodynamics engineers; dynamics engineers; electronic research engineers; servosystem engineers; electronic systems engineers; theoretical physicists; infrared physicists; hydrodynamicists; ocean systems scientists; physio-psychological research specialists; electrical—electronic design engineers; stress engineers; and instrumentation engineers.

Scientists and Engineers are cordially invited to write: Mr. E. W. Des Lauriers, Manager Professional Placement Staff, Dept. 3105, 2416 N. Hollywood Way, Burbank, California. All qualified applicants will receive consideration for employment without regard to race, creed, color, or national origin. U.S. citizenship or existing Department of Defense industrial security clearance required.

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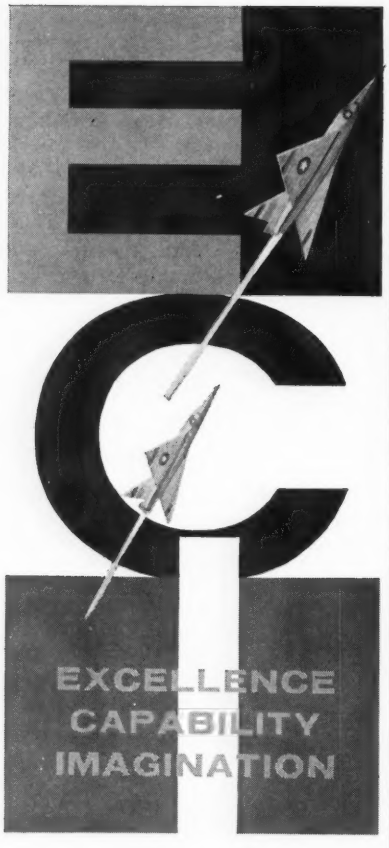
WE'RE CLOSER THAN YOU THINK...

Reading clockwise: Venus, Moon, Mars. Approximate distance from Venus to Earth, 25,000,000 miles; from Moon, 240,000 miles; from Mars, 50,000,000 miles.

Photos courtesy of Mount Wilson and Palomar Observatories.



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mission, and then to require a larger ground antenna (but with the same gain) in order to retain the original system capability.

Cosmic-ray probe at edge of solar system. This communications system is essentially the same as that of the Mars orbiter, except that the increased distance to the probe is compensated by a reduction in information transmission rate and quality.

The Tracking Problem

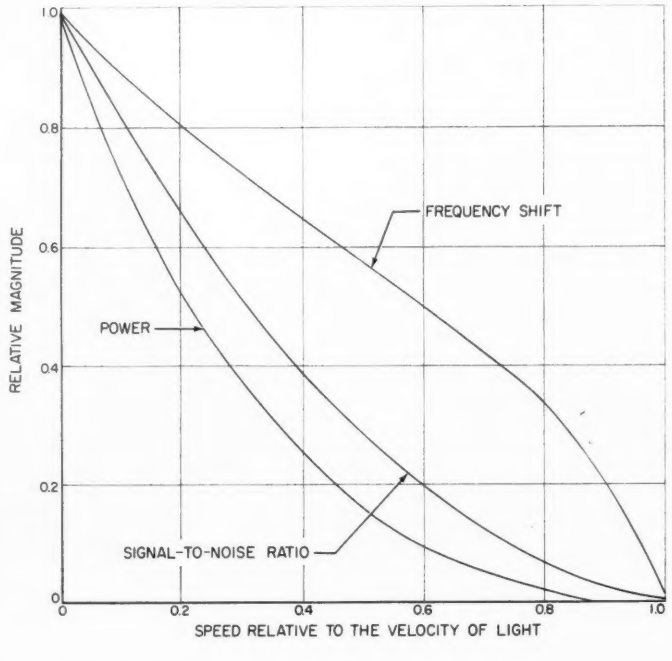
Tracking of space probes is essential in order to evaluate launching performance, to permit vernier corrections to the trajectory, and to point highly directional ground antennas. One of the most difficult tracking phases is the search and acquisition phase necessary at a remote station which must track the probe on the first pass after launch. To relieve this problem, the beamwidth of the ground antenna is made at least 10 deg wide (gain of 270). Countdown and pointing information are also transmitted to the remote station as rapidly as earlier data make it possible. Angular tracking information from such stations is not particularly accurate; but doppler, ranging, and telemetry from them can be excellent.

Determining orbits of a satellite or spaceprobe accurately is in some ways easier than determining the trajectory of a guided missile. It is possible to take advantage of the very long tracking intervals and the use of widely spaced stations to achieve accuracies of 10 to 50 times the single-measurement accuracy of any one station. For example, the ground tracking stations for the Pioneer IV lunar probe were capable of angular accuracies of 1.0 to 0.1 deg (depending on the station), and yet the orbit was accurately determined to an accuracy of better than 0.01 deg within one day after launch.

One of the most valuable additions to tracking systems in recent times has been the addition of computers which cannot only smooth the data but also can solve for various station errors and eliminate them. A computer treats unknown (but generally constant) station errors simply as further unknown parameters in addition to the orbital ones. Inasmuch as computers can often solve for several-dozen unknown parameters, they not only define the orbit but also evaluate the stations. The calculations depend upon the fact that station errors will create apparent effects in the trajectory which could not occur under Kepler's laws of motion for the vehicle. A simple example is an error in the station clock, an error which would make it appear that the probe had instantaneously changed position when the station first began tracking.

The determination of an accurate orbit for a deep-space probe is critically dependent upon measurements made while the probe is moving rapidly upward through the gravitational field of the earth. The gravitational gradient field is much more significant in this situation than for

Relativistic Communications



guided missiles, because the final orbit of the probe is very sharply influenced by the precise way in which the probe passes through the field. As a consequence, crude measurements made while the probe is leaving the earth can be far more definitive of the final orbit than very precise measurements made when the probe is far away.

The same situation is perhaps even more obvious when the probe reaches the gravitational field of a target planet. The probe's range and relative velocity from the earth are then strongly influenced by the local gravitational field, and such changes provide a far better indication of the position of the probe relative to the planet than would be the case if no gravitational field were present.

Using angular accuracies of a few tenths of a degree, velocity measurements accurate to 1 m/sec, and ranging information with a precision of 10 m, it is possible to direct spaceprobes to within 20 km on the surface of the moon or to within a few thousand kilometers of the planets. Having been directed to this accuracy from the earth, the probes can easily direct themselves to almost any desired location either on the surface of, or in orbit around, the target.

One of the most surprising features of space tracking is that tracking accuracy need not be fantastically precise. Instead, the accuracies are comparable to those demanded of a medium-range missile traveling from one point on the surface of the earth to another.

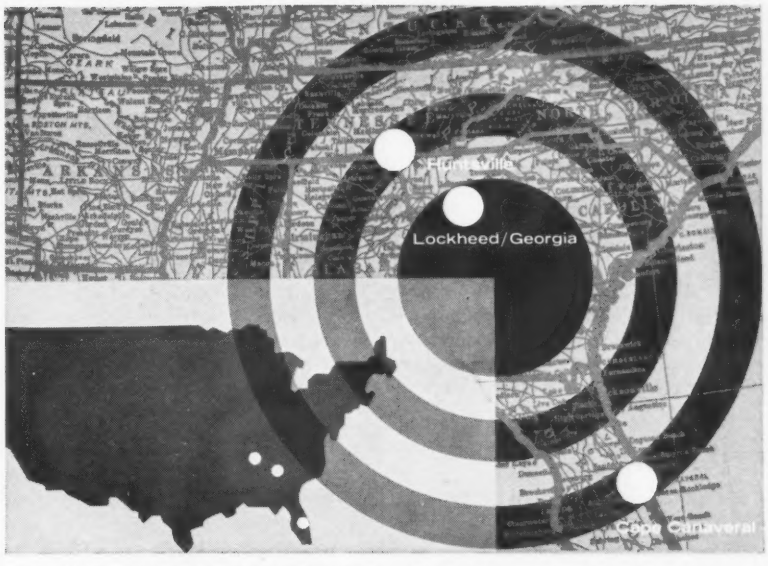
The Future

Any discussion these days is only up to date for a few years at the most. Here are some events which will make a revision of *this* paper necessary.

In the near future, electric propulsion systems will probably come into active use to propel vehicles from earth-satellite orbits out to the planets. It is characteristic of these propulsion systems that they make available a very large source of raw electrical energy—at least kilowatts and, later, megawatts. The space communicator will almost overnight be confronted with more available power than he can possibly convert into radio-frequency energy.

Communications required from vehicles entering a planetary atmosphere at high velocity will be markedly more difficult. The problem will be compounded when the vehicle lands on the surface of the planet and is then carried along by the planet's rotation. Parenthetically, the problem of landing on the moon is considerably simpler, both because of its lack of atmosphere and because the same surface of the moon is always presented to the earth.

In the still more distant future, the advent of vehicles traveling at relativistic velocities will create communications effects which are normally unknown to the space communicator. The doppler shift, of course, will be extremely large. Data transmission rates will be drastically affected. In addition, the apparent direction of the vehicle will be markedly different from its actual direction. As if to confuse the space communicator completely, the apparent antenna pattern of the relativistic vehicle's antenna will be swept sharply forward. This concentration of energy in the forward direction is a familiar phenomenon to nuclear physicists observing the radiation from a relativistic electron impacting on a plate. The apparent result to an observer on the earth is a decrease in received power and in signal-to-noise ratio, as indicated in the graph on page 86. For the space communicator—when that time comes he will again have entered a new era.



STRATEGIC AEROSPACE CENTER ▪ Lockheed/Georgia is next door to Huntsville and Cape Canaveral. This strategic geographic location eliminates excessive transportation costs, makes technical liaison more efficient, and reduces the overall time span of aerospace programs. And the Georgia Division is big enough physically to handle any program yet conceived—big enough in capability to take on the full gamut of advanced research and manufacturing jobs. **LOCKHEED**/GEORGIA
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♦♦

People in the news

APPOINTMENTS

Col. Charles H. Roadman, a special assistant to the director of NASA's Office of Life Sciences, has been appointed deputy director of that office.

Lloyd A. Wood has been appointed director of the Physical Sciences Div. of the Air Force Office of Scientific Research.

Nathan Marcuvitz has been named vice-president for research at Polytechnic Institute of Brooklyn.

G. U. Sorger has been appointed assistant professor at the new Institute of Measurement Science of George Washington Univ., established in cooperation with the National Bureau of Standards and the Martin Co.

Charles H. Townes will become provost of the Massachusetts Institute of Technology, sharing general supervision of its educational and research programs with MIT's president.

Philip F. Fahey Jr. has joined the technical staff of Lockheed Aircraft's California Div., Spacecraft Group. He formerly was chief, Technical Support Div., directorate of rocket propulsion, Edwards AFB, Calif.

Theodore von Karman will lend technical guidance to the new Research and Development Center of Tool Research and Engineering Corp., where he is the chief scientific consultant.

John I. Lerom becomes manager of United Technology Corp.'s Washington, D. C., operations on June 1. **Mitchell Gilbert** and **Edward Fisher** have been named principal scientists in the newly established Physical Sciences Laboratory, and **Christian Frey** will head the Materials Branch.

J. M. Cumming will head Rocketdyne's new Small Engines subdivision in Research and Engineering. **Edward D. Weisert** has joined the company's Research Dept.

Benjamin F. Ruffner has been named chief of technical staff, Boeing's Aero-Space Div.

J. Ward Wright becomes assistant manager and **R. L. Tibbs** representative for electronics requirements at the Martin Co.'s Huntsville, Ala., office.

Winfield E. Fromm has been upped to director, Research and Systems Engineering Div., Airborne Instruments Laboratory, a division of Cutler-Hammer, Inc.

Roger L. Sisson has been appointed manager, program analysis, technical staff, Ford Motor's Aeronutronic Div.

Camille M. Shaar Jr. has been named to head aerospace operations for the Defense Systems Div. of General Motors, with headquarters at Santa Barbara, Calif.

Morris Handelsman has been promoted to associate director of advanced military systems, Defense Electronic Products, Radio Corporation of America.

Horace R. Moore has been named manager of the newly formed Spectroscopy Dept., Quantum Electronics Div. of Electro-Optical Systems, Inc., and **Richard E. Bradbury** has joined the department as a physicist. **Bernard E. Kalensher** has joined EOS as a senior physicist in the Fluid Physics Div.

Edward A. Williams and **Robert P. Dutton** have been elected vice-president of operations control and government representation, respectively, Collins Radio Co. **H. C. Briggs** has been named vice-president, Collins Radio International CA.

John W. Collins has been named president of Grove Valve and Regulator Co., a subsidiary of Walworth Co. Previously, Collins was senior vice-president and chief executive officer of GVR.

R. D. O'Neal, vice-president, engineering, and **R. H. Isaacs,** vice president, government relations, have been elected to Bendix Corp.'s administration committee. **John A. F. Gerrard** has been appointed director of electronics for Bendix-Pacific Div.

John Cammarata has been named manager, product reliability, Arma Div., American Bosch Arma Corp.

Brig. Gen. Kenneth E. Fields (Army-Ret.) has been elected executive vice-president, Bulova Watch Co.

Edson B. Gould III has been promoted to manager of reliability and quality, Hughes Aircraft's Semiconductor Div. **Daniel Binder** has joined Hughes' nuclear electronics lab as head of the Nuclear Measurements Dept.

Donn L. Williams has been named vice-president and general manager for armament and flight control operations of Autonetics.

Alfred E. Lonnberg has been elected president of Sanborn Co. **George F. Benoit** has been appointed director of engineering.

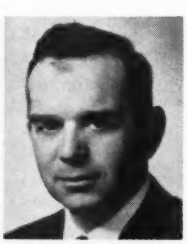
Gifford K. Johnson has been named president and chief executive officer of Chance Vought Corp., and **J. R. Clark** has been appointed vice-president and general manager of the Astronautics Div. **Charles F. Gell,** chief of life sciences for the division, will also serve as clinical professor of physiology at the Univ. Texas' Southwestern Medical School.

William M. Smith has been appointed vice-president and manager, Bell Aerosystems Co.'s Aerospace Rockets Div., and **Frank H. Andrix** has been named assistant vice-presi-

(CONTINUED ON PAGE 121)

Ruffner

Fromm



Handelsman

Collins

Cammarata

Fields

NEXT STOP: MARE IMBRIUM

One of the primary needs in the next generation of our space program is for a reliable "space bus"—a vehicle versatile enough to carry a variety of exploratory packages to the moon and possibly to the near planets. Once it is injected into a lunar or planetary trajectory, this bus will have to guide itself to its destination, accomplish a soft landing, release and activate its payload.

The problems involved in the design and fabrication of such a vehicle, as well as the various payloads it might be expected to deliver, are being intensively explored at Norair. These investigations cover guidance, communications and position sensing systems, thermal and environmental conditioning, structural and material development and a host of other in-house capabilities. Expanded working groups in all essential areas are coordinating their efforts in the search for practical, integrated solutions to these problems.

This determination to research problems as thoroughly as possible, the ability to concentrate such a wide range of technologies toward their solution, and the added ability to translate the results into working hardware are prime assets of Norair in the space age.

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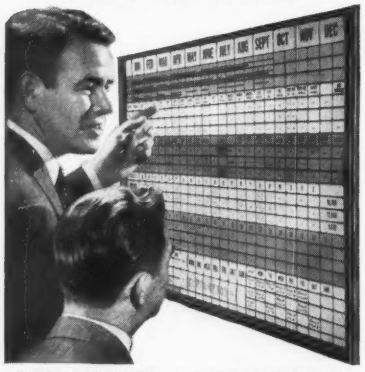

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Practical Problems

(CONTINUED FROM PAGE 35)

Another and narrower problem has to do with the particular technical standards which must be attained and maintained. There are established standards covering such matters as bandwidth and signal-to-noise ratio, and much more detailed and recondite matters as well. Among these is a recommended practice that the overall one-way time delay of a telephone circuit shall be less than a quarter of a second. This is somewhat less than the propagation time to a 24-hr, 22,300-mi-high stationary satellite and back to earth.

This allowable delay was set many years ago for what seemed wise reasons. Even using a four-wire circuit, with entirely separate paths between each transmitter and receiver, the effect of this delay is noticeable in some conversations. In actual telephony, two-wire circuits are used which cause an intolerable echo when the delay is so long. To overcome this, echo suppressors are used on long circuits; these interrupt transmission while a signal is being received. This can result in unfortunate deletions from, or blocking of, conversations.

The degradation inherent in the delay associated with stationary satellites must be carefully evaluated. It is clear, however, that a 24-hr satellite can never give us quite as good a telephone circuit as those we now have via cable.

Launching Costly, Risky

The launching of satellites is a difficult and expensive matter. Experience has shown that at present new or modified launching vehicles are uncertain in their operation, and even vehicles which have been used many times are not unfailing. This, together with the high cost of launchings and the higher costs of developing a new vehicle, convinces me that the only economically practical way to launch a satellite is to use the best-adapted, well-tried, currently available vehicle.

Fortunately, other space needs have given us vehicles suitable for the launching of communication satellites and further work will give us better vehicles, quite independently of any needs for satellite communication. We should take advantage of this fact rather than burdening satellite communication with extremely expensive and necessarily limited vehicle-development programs.

There has been much discussion of the tracking of satellites. It has frequently been argued that the fact that a stationary satellite need not be tracked will lead to a substantial economic advantage. It has even been proposed that stationary, nonsteerable antennas might be used. I'd certainly hate to gamble on a 24-hr satellite staying in the beam of a stationary antenna in an experiment or even in an early and untried system.

Tracking is a difficult problem. But, also, electronics is now a sophisticated and powerful art. During the Echo experiment, by using predicted positions the Echo satellite was tracked to ± 0.2 deg, and sometimes to ± 0.1 deg, when the data was fresh. This is not good enough for a commercial system using larger antennas, but better tracking can be attained. Further, when one considers actual costs, the provision for tracking will not be a major factor in the cost of ground terminals and it will be an even smaller factor in the cost of an overall system, including the cost of launching and replacing satellites. The cost of launching and replacing satellites will be the greatest cost in a satellite communication system.

This makes the life of satellites one of the most critical problems in a satellite system. A factor of a very few-fold in life could make or break a satellite system.

Space poses many inadequately explored problems important to satellite life. Most active space payloads depend on solar cells, together with storage batteries, for electrical power. Sunlight has an energy of about 130 w per square foot, and solar cells can turn about 10%, or 13 w, of this into electrical power initially.

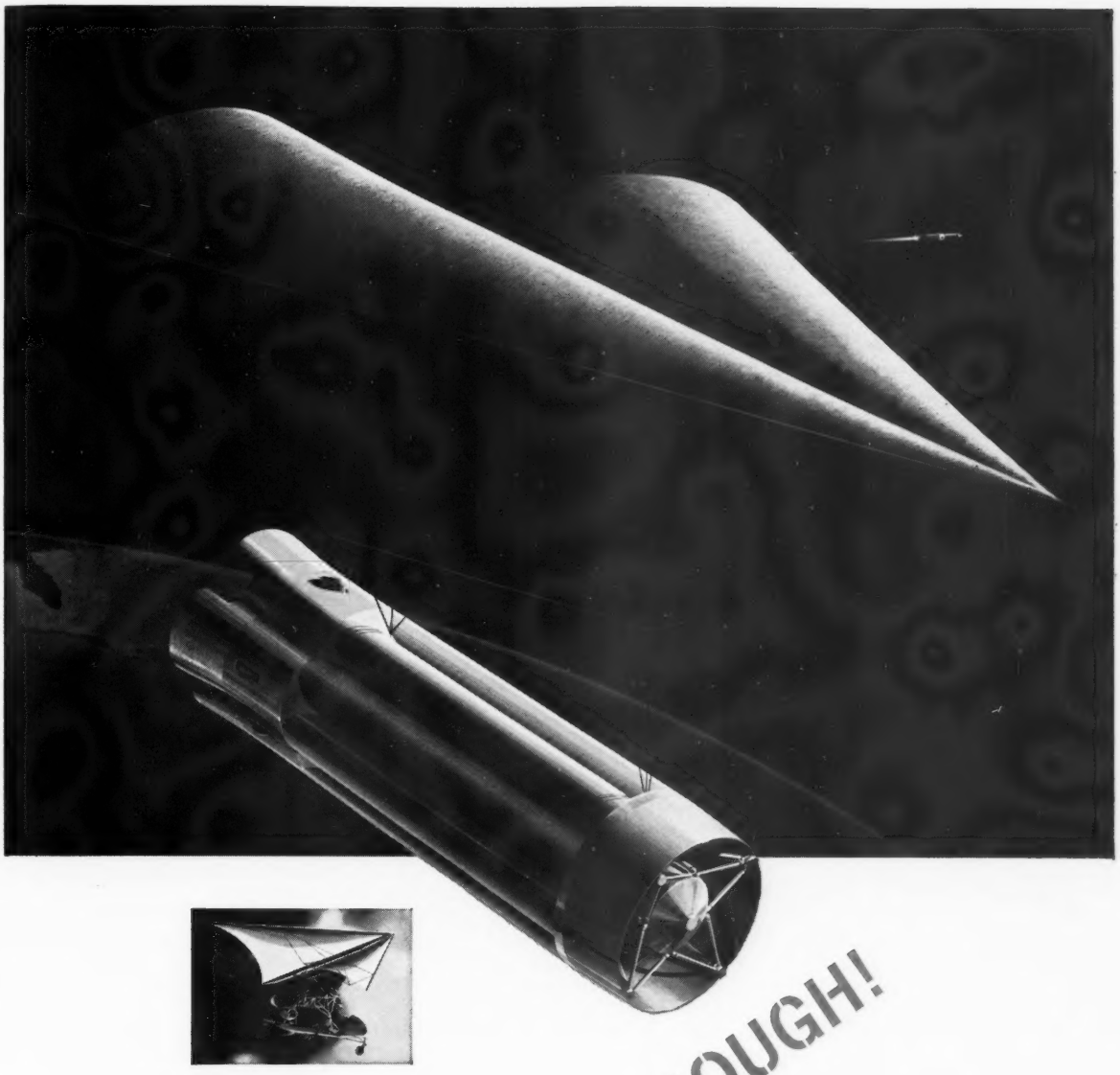
Unfortunately, radiation pervades space. Cosmic radiation has little effect on solar cells. Less than a tenth of an inch of glass, quartz, or sapphire will shield solar cells adequately from the electrons of the outer Van Allen belt, which is most intense about 13,000 mi above the earth's surface. It appears impossible to protect solar cells against the effect of the protons of the inner Van Allen belt, which is most intense at an altitude of around 2000 mi and which extends to an altitude of perhaps 5000 mi.

While the discovery and exploration of the Van Allen belts is a major scientific feat, the extent, intensity, and composition of its radiations have not been carefully measured, nor their changes with time accurately determined. While we know how much degradation radiation of various energies causes in solar cells, our uncertainties concerning the nature and amount of radiation which a satellite will encounter are great. We are uncertain by perhaps a factor of 12 as to when the efficiency of a solar cell will have fallen to some preset design limit—say, 5%. Our best present estimate is that the solar cells in a satellite a few thousand miles high would last for from several months to several years. Solar cells on higher satellites would last longer.

Space Hazard to Devices

While all solid-state electronic devices are subject to the hazards of radiation, transistors and diodes are in general less sensitive to radiation than are solar cells. Further, they are better protected, both by metal encapsulation and by location within a metal-clad satellite structure. This does not mean, however, that satellite electronic equipment other than solar cells does not face special problems and hazards in space. For instance, all equipment must withstand tens of G of acceleration during launch.

Ultimately, only radiation cooling is available. Heat must be conducted to radiating surfaces. There can be convection even in a pressurized container only if the satellite is spun, because there is no weight in an orbiting satellite. In an environment of al-



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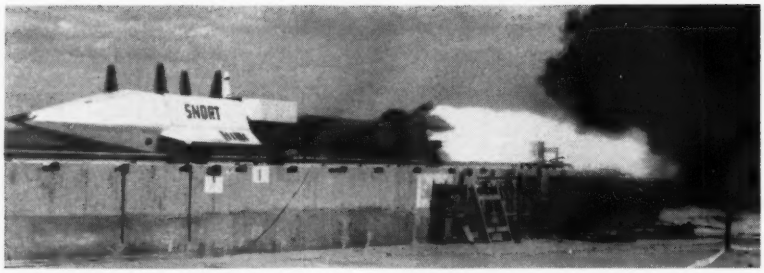
Ryan offers challenging opportunities to engineers



Zip Down Snort

Testing a guidance system, a rocket-powered sled starts to move down the Snort track at the Naval Ordnance Test Station, China Lake, Calif. Developed by Aerojet-General's Spacecraft Div. in Azusa, Calif., this sled, the AJ10-13, is powered by two ceramic-lined Bomarc combustion chambers burning nitrogen-pressurized RFNA and jet fuel. The twin chambers give some flexibility in varying G loads, up to a maximum of 10 G. The AJ10-13 was first procured to test Polaris guidance.

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ternating sunlight and shadow, the temperature variation of the exposed parts of a satellite will be large, though the thermal capacity of interior parts can reduce temperature fluctuations.

Vacuum and gas at atmospheric pressure are good insulators, but during ascent pressures are encountered at which a discharge can be initiated at a comparatively low voltage. Once in orbit, pressurized containers may leak. The seals of storage batteries sometimes leak. Vapors from apparatus can produce appreciable gas pressures in enclosed spaces even if these are not completely gas tight.

The dependability, the life of satellite electronic equipment, is of primary importance to satellite communication. The chief initial cost of a satellite communication system will be the cost of launching and replacing satellites. Unless the life of satellites is many years, the chief operating cost will be the cost of replacing satellites. The practicability of satellite communication depends on obtaining long life in the novel and hazardous environment of space.

Undoubtedly, long life can be attained in space. The Vanguard transmitter is still functioning after 3 yr in orbit. This is a very simple transistor oscillator, and enough solar cells were used to keep it going despite a drastic fall in their efficiency. More complicated satellite payloads have lasted as long as a year (an unsatisfactorily short life for a communication satellite), but many others have failed after a few weeks or a few months in orbit, and some have failed in whole or in part during launch.

The operation of apparatus on command from the ground has proved particularly hazardous. One would expect apparatus to function most reliably when it runs continuously without interruption, and experience indicates that this is indeed the case.

So far, I have discussed only the problems of the minimum essential electronic equipment for an active satellite. This equipment could be enough for a communication satellite, because low satellites could be operated unoriented, or with very crude orientation. Of course, there are advantages to orienting any satellite, for this cuts down the power required in a low satellite appreciably, and that required in a high satellite greatly. However, orientation could cost more than it is worth if it resulted in decreased satellite life. And, stationary satellites call for station keeping as well as for orientation.

How Long for Orientation?

What is the state of the art of orientation and station keeping? Atlas nose cones have been successfully oriented for tens of minutes. Discoverer satellites have been oriented for days. If communication satellites are to be useful and to compete economically with cables, they must last for years.

Will gas valves operate for years without leaking? Will bearings operate for years in vacuum without freezing? What is the chance that during its years of operation some brief malfunction of orientation gear will set the satellite to spinning? Just how dependable will orientation and station-keeping gear be? If such equipment depends on commands from earth, can we really count on its responding to our commands and on its not responding to signals of other origin? Today we have only conjecture. We will be able to answer such questions only on the basis of experiments and experience.

We might wish to orient a satellite in a low orbit. The magnetic field is very small at an altitude of 22,300 mi, and it changes with time, for it depends not only on the magnetism of the earth but on the flow of charged particles from the sun. At altitudes of a few thousand miles, the earth's field is strong enough to serve as a reference or to provide an appreciable force in orienting a satellite. But this means of orientation has not been adequately explored experimentally.

In Line with Tension

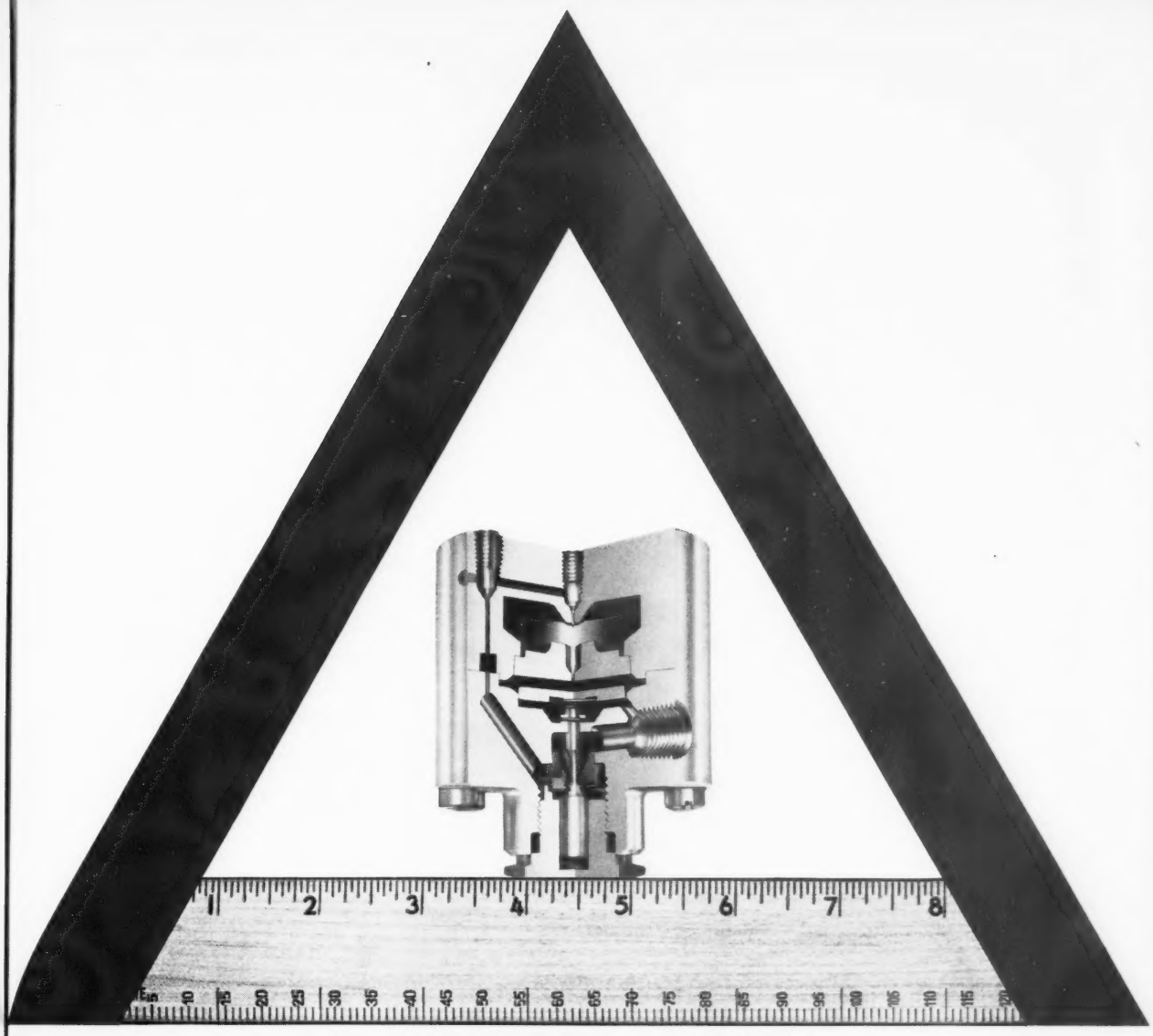
We might make use of another force in orienting a low satellite. For a given angular velocity, centrifugal force increases with increasing radius of orbit, while the force due to gravity decreases with increasing radius. Imagine a satellite made up of two equal weights tied together with a wire and aligned radially with respect to the earth. The centrifugal force will be greater on the outer weight, and the force of gravity will be greater on the inner weight. There will be a small tension in the wire. If displaced, the system will tend to return to its radial orientation. But, this force is very small.

Tiros I and II, the weather satellites, have been spin-oriented. This keeps the axis of spin pointed in one direction. As a satellite rotates in the earth's magnetic field, eddy currents gradually slow down the rate of spin, and spin-oriented satellites must be respun from time to time.

While the orientation of satellites in low orbits may be easier than the orientation of 22,300-mi-high satellites, we have too little experience to enable us to evaluate the advantages and hazards of various means of orientation.

The power required affects the life profoundly. Life tests show that 5-w traveling-wave tubes have not failed after 4 yr, and we believe that carefully designed 2-w tubes, which would be sufficient for a carefully designed satellite communication system, would have an assured life of 10 yr or more. On the other hand, we just don't know how to make long-life tubes for hundreds of watts, and even tens of watts pose serious, unsolved problems.

Further, low power is economical from another point of view. Satellite weight is governed by, and is nearly proportional to, power. A lower power makes it possible to launch



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Grove Mity-Mite®... light, compact, accurate for reducing, relief and back pressure control. Grove Mity-Mite regulators are materially smaller than conventional regulators of comparable capacities. They are available for pressure reduction, combination reduction and relief, and back pressure services. Mity-Mites utilize the same proven gas dome-loaded principle of Grove Powreactor® Regulators—a design that has set engineering standards for every pressure regulator used in aerospace today! Mity-Mites may be supplied in externally or internally loaded models in dural or 18-8 (type 303) stainless, from ¼" to 1", with inlet pressures to 10,000# psi; outlet pressures to 6,000# psi. For complete engineering data, send for Bulletin #940-H.

GROVE REGULATORS

GROVE VALVE AND REGULATOR COMPANY

a subsidiary of Walworth Oakland and Los Angeles, California

Another Way Grove Sets Regulator Standards for Others to Follow

more satellites with a given vehicle. Still another advantage of low power is that it tends to reduce interference.

How can one design and build a system so that a low power aboard the satellite is sufficient? The power required is determined by the noise from the sky, which is a function of frequency, by any thermal noise picked up from the earth, which is very hot compared with the sky, by noise introduced by the receiver, and by the form of modulation used.

In the frequency range between 1 and 10 kilomegacycles, the noise from the sky corresponds to a temperature of less than 20 K for an antenna pointed more than 7 deg above the horizon. The noise rises during rain, and this must be taken into account as a possible source of system outage. A practical maser amplifier adds a noise corresponding to about 10 K, and this noise can be reduced further.

The temperature of the earth is around 300 K. To avoid receiving radiation from the earth, we can use a horn reflector antenna, such as that used in the Echo experiment.

The Echo receiving system had an overall equivalent noise temperature of about 24 K with the antenna pointed at the zenith. Much of this noise was associated with experimental features and could be eliminated. We can expect to attain a noise temperature of 15 K in the near future and below 10 K ultimately.

Modulation Effects

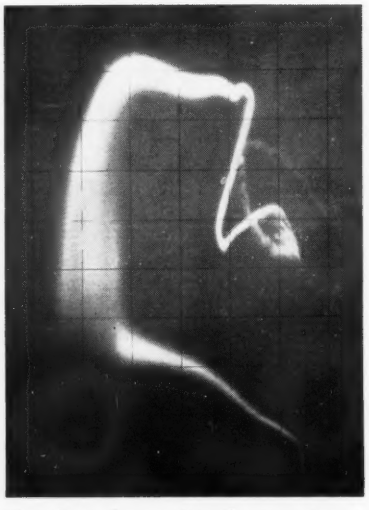
I have noted that the power required depends on the method of modulation which is used. By using wide-deviation frequency modulation, in which the transmitter frequency is varied in accord with the signal over a frequency range of many times the bandwidth to be transmitted, the signal-to-noise ratio obtained using a given transmitter power is improved. If the frequency is varied up and down from the center frequency by 10 times the bandwidth, the gain in signal-to-noise ratio is about 100 times. This, however, requires the use of a radio-frequency bandwidth of about 100 mc to transmit a television or other signal having a bandwidth of 5 mc.

Ordinarily, in receiving an FM signal, the bandwidth of the receiver must be as wide as the total range of frequencies covered by the received signal—100 mc in the case just cited. But for the receiver to operate at all in the presence of noise, the signal must be around 20 times as powerful as the noise. If the receiver bandwidth is broadened to receive a wide-deviation FM signal, the receiver picks up noise, and this minimum ratio of signal to noise may be hard to obtain.

Fortunately, in 1939, J. G. Chaffee described a receiver for FM signals with a bandwidth small compared with the range frequencies over which the transmitter sweeps. In this receiver the output is "fed back" to alter the tuning of a comparatively narrow-band receiver, so that the receiver is always tuned to the received signal, however that signal frequency is swept back and forth. The use of Chaffee's FM-with-feedback receiver substantially reduces the transmitter power required in a satellite communication system.

We should note that other forms of broadband modulation, including various pulse-modulation systems, could be used to obtain an advantage comparable to that gained with wide-deviation FM and an FM-with-feedback receiver.

An Astronautical Line In Italian Skies



The first of a series of upper-atmosphere experiments being conducted jointly by the Italian Commission for Space Research, headed by Luigi Broglio, and NASA produced this sodium-vapor cloud in Italian skies. The first shot in this international program of space research took place in January and employed an NASA-supplied Nike-Cajun launch vehicle and sodium payload. The program is expected to introduce eventually Italian-produced rockets. Data from the tests will be published for international use. For the significance of such experiments, see Murray Zelikoff's article on "Artificial Modification of the Upper Atmosphere" on page 46 of the July 1959 *Astronautics*.

Considering sky noise, the noise of a maser receiver, and broadband modulation, what power do we require in a satellite communication system capable of transmitting a television signal or from 600 to 1000 telephone signals? We will assume a horn-reflector antenna with an aperture 60 ft square. For an unoriented satellite radiating equally in all directions at a height of from 2000 to 5000 mi, the required power is around 2 w. Almost exactly the same power will serve for an oriented 22,300-mi-high satellite with a directive antenna that beams a signal over the whole disk of the earth.

Beyond these particular problems, there are many involved considerations of a systems nature. A 24-hr satellite system requires fewer but somewhat more complicated and heavier satellites than a low-altitude satellite system. Fewer high satellites would be needed to provide continuous or almost continuous service. However, the failure of one satellite in a many-satellite system degrades service scarcely at all.

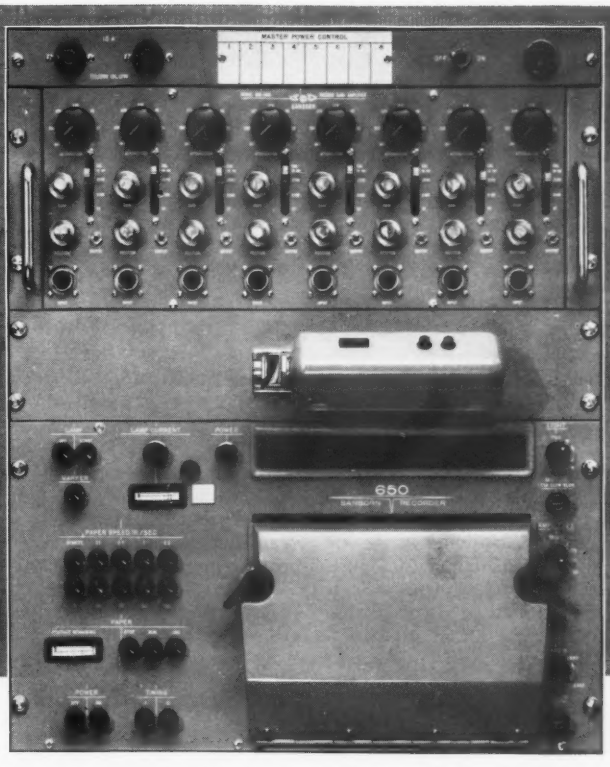
Further, if some number of satellites assured the availability of at least one satellite for a given path—say, 99.9% of the time—two satellites would be available for a smaller fraction of the time, three for a still smaller fraction, and so on. These extra satellites could be used to provide communication over secondary paths on which the greater interruption of service could be tolerated. Of course, any given satellite could be used over one part of the globe at one time and over another part of the globe at another time.

Ground-Space Interference

Possible interference between satellite systems and ground microwave systems is an extremely important matter. Several general principles are clear. Anything that makes the powers involved in a satellite system less minimizes interference with ground systems. The low-satellite transmitter powers allowed by maser receiver and broadband modulation will not interfere with ground communication receivers at all. High-quality ground antennas with low sidelobes, and particularly horn-reflector antennas, tend to reduce interference.

In attaining many satellite channels at once, one must rely on both frequency separation and on the use of satellites in many parts of the sky, which is made possible by highly directive ground antennas. It appears that the use of many satellites will be possible only through the protection against interference afforded by

DC to 5000 cycles over an amplitude of 4" peak to peak



NEW SANBORN "650" SYSTEM OFFERS DIRECT READOUT, 8 TO 24 CHANNELS, ALL SOLID STATE CIRCUITS, FOR RACK MOUNTING OR INDIVIDUAL CASES.

Here's the *one* system that lets you record inputs from DC to 5 KC within 3 db at 4" peak-to-peak amplitudes, without changing galvanometers. The "650" system consists of an 8-channel medium gain, general purpose amplifier unit driving a high speed, high resolution optical oscillographic recorder. It can be easily built into your system, packaged in a mobile cabinet or housed in individual cases. The single-chassis, 7" high amplifier module has 8 separate channels, *complete from floating and guarded inputs to galvanometer outputs;* each channel comprises a front end modulator and input transformer, carrier amplifier, demodulator, filter and driver amplifier. Power Supply and Master Oscillator Power Amplifier are built-in. All amplifier elements are plug-in transistorized units for easy servicing.

Immediately readable recordings are made on 8" wide daylight-loading ultra-violet-sensitive charts which require no chemical development. Features of the 12¼" high recorder unit include 9 electrically controlled chart speeds from ¼" to 100"/sec; calibrated monitoring screen; automatic trace identification and timing lines at 0.01 or 0.1 sec. intervals; amplitude lines spaced 0.1" apart which can be blanked from ¼, ½, ¾ or all of chart. Recorder is available with an 8-, 16- or 24-channel galvanometer block which is then equipped with the number of galvanometer elements desired by the customer. Both the Recorder and Amplifier are also available as individual units for use with other equipment.

SENSITIVITY 20 mv input gives 8" deflection; 12 attenuator steps to X5000, smooth gain control.

INPUT RESISTANCE 100,000 ohms all ranges, floating and guarded; DC source resistance must be kept below 1000 ohms on mv ranges only.

COMMON MODE PERFORMANCE Rejection at least 140 db at DC, tolerance to ±500 volts, max.

GAIN STABILITY Better than 1% to 50° C. and for line voltage variation from 103 to 127 volts.

LINEARITY 1½% of full scale (8 in.)

NOISE 0.02" peak-to-peak, max.

MONITOR OUTPUT On front panel; provides ±1v full scale across 100,000 ohm load

POWER REQUIREMENTS 103-127 volts, 60 cycle AC; 625 watts

Contact your Sanborn Sales-Engineering Representative for complete specifications and applications engineering assistance. Offices throughout the U. S., Canada and foreign countries.

SANBORN COMPANY
INDUSTRIAL DIVISION
175 Wyman St., Waltham 54, Massachusetts

broadband modulation, so that more actual usable communication will be made available through using a large rather than a small bandwidth in transmitting a given signal.

This problem of interference is very complicated, and there is much to be learned. In the light of our present knowledge it seems best to try to use low powers and broadbands.

The choice among various possible satellite systems must depend on the established state of the art and on a very careful weighing of various considerations. Through the favorable outcome of the Echo experiment, the capabilities of a passive satellite have been established. It seems to me that, granting an equally favorable outcome following an experimental launching of a simple active satellite, a practical and economical communication system making use of many low-altitude satellites in random orbit need not be many years distant. This is what we are now working toward at the Bell Laboratories.

As time passes, various satellite communication systems will be tried, and I certainly expect that systems involving 24-hr satellites will be built. If at this time I emphasize one general approach to satellite communication, it is because it seems to me appropriate to the particular problems and capabilities of these years. ♦♦

Extraterrestrial Linguistics

(CONTINUED FROM PAGE 47)

demonstrate gadgets, especially munitions, at which our species excels. Other than publicly killing one another, we can perhaps demonstrate our intelligence by collecting biological specimens to raise in captivity. Such scientific curiosity is an unmistakable sign of intelligence, although with a notable drawback: If our specimen belongs to the dominant species, his capture and imprisonment may be regarded as an act of war.

Now we come to the really significant question. Suppose we have passed the I.Q. test, resolved all the semantic questions, and have an effective communications link going. What do we talk about? Bell Telephone and Western Union assume their subscribers already have something in mind to say, so that classical information theory turns out to be of no help. Ruling out such commonplaces as baseball scores, the weather, and back-fence gossip, I have compiled the following list of likely topics for discussion with our extraterrestrial neighbors: (1) Help! (2) Buy! (3) Convert! (4) Vacate! (5) Negotiate! (6) Work! (7) Discuss!

Each of these topics merits a brief elucidation:

(1) Help! Assumes we have encountered a superior civilization and want their help in solving our earthbound problems or fighting our internecine battles.

(2) Buy! Presupposes that some basis for mutually profitable trade exists and should be acted on.

(3) Convert! Suggests that as missionaries from the Chosen Planet we have undertaken to spread the Good Word that the Galaxy is coming to an End.

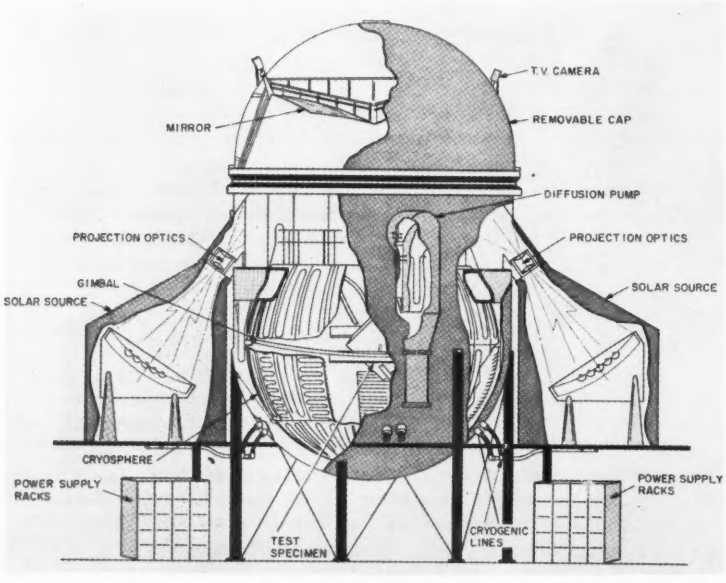
(4) Vacate! Means that we like the planet, and figure that we can defeat the inhabitants.

(5) Negotiate! Means that we are looking for new members in OPTO (the Occidental Planetary Treaty Organization).

(6) Work! Supposes that we've uncovered a good source of cheap labor.

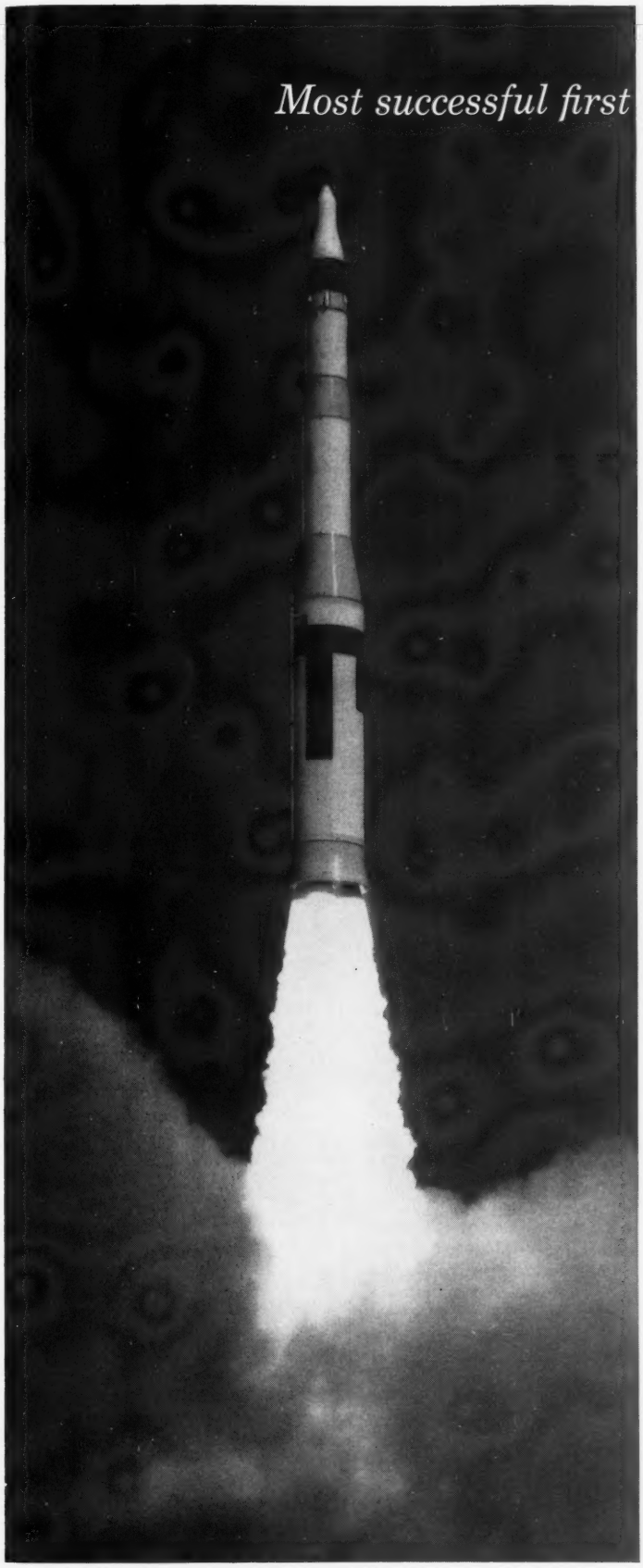
(7) Discuss! Presumes that there is no common environment which we and they can share. Only in such a case does the history of our species offer encouragement for the prospect of free mutual interchange of ideas, experiences, and scientific theories.

Naturally, we must not risk telling too much until we know whether the Extraterrestrials' intentions toward us are honorable. The Government will undoubtedly set up a Cosmic Intelligence Agency (CIA) to monitor Extraterrestrial Intelligence. Extreme security precautions will be strictly observed. As H. G. Wells once pointed out, even if the Aliens tell us in all truthfulness that their only intention is "to serve mankind" we must endeavor to ascertain whether they wish to serve us baked or fried. ♦♦



GE Space Simulator Takes Large Payload

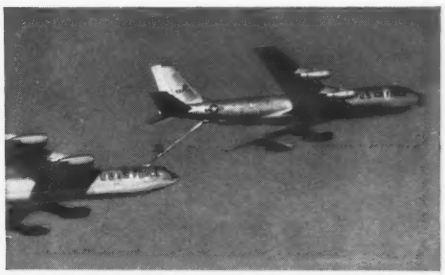
The illustration depicts a $6 million space simulator being built for GE's Missile and Space Vehicle Dept. at the company's Space Technology Center, Valley Forge, Pa. The 32-ft-diam, 54-ft-high environmental chamber will accept space vehicles as long as 20 ft and as heavy as 5 tons. In it, collimated rays from banks of newly developed 5-kw zenon arc lamps and a 22-ft mirror will stimulate the sun's radiation and image distance. Pressure will go as low as 10^{-9} mm Hg, well temperatures as low as 20 K. Expected to be in operation by the end of the year, the simulator will have as one of its first applications testing of the Project Advent earth-period communications satellite, which MSVD is working on.



Most successful first flight in missile history

Historic first firing of Minuteman, the U. S. Air Force's first solid-fuel intercontinental ballistic missile. Completely successful, this flight marked the first time in history that so many missile components were tested on initial flight: three rocket stages, full guidance system and nose cone. Compact, quick-firing Minuteman missiles, scheduled for operational status by mid-1962, will be stored ready for instant action in underground silos and on special trains. Boeing is responsible for Minuteman assembly and test, design and development of launch control and ground support systems.

Capability has many faces at Boeing



SKY TANKER. Boeing KC-135 jet tanker refuels bombers and fighters to provide greatly extended range. This versatile Boeing jet is also a military transport. The United States Air Force recently ordered 30 C-135s, cargo-jet version of KC-135.

TESTING. TESTING. Boeing electronic system tests effectiveness of radar and countermeasures systems. Boeing is widely active in electronics—in research, design, manufacture and test, and in the assembly of systems for Air Force's BOMARC and Minuteman missiles, and Dyna-Soar space-glider.

BOEING

Observatory 16 Miles Up
...FROM PERKIN-ELMER

An unhindered view of the planets and other celestial bodies . . . via a special telescope-camera from Perkin-Elmer . . . is the mission of the unmanned balloon flights of Project Stratoscope II.

This 4500 pound astronomical research instrument includes electronic servomechanisms which give it a pointing accuracy of 1/30 second of arc and electronic controls which permit the 36" aperture optical system to be focused by remote control to 1/8 of a wave length of light. Extensive radio command and telemetry equipment for control of the instrument was also the responsibility of the electronic engineers on this project.

Assignments equal to the challenge of Project Stratoscope II are available for Engineers and Scientists experienced in the following areas:

- ELECTRO-OPTICAL-MECHANICAL SYSTEMS
- ELECTRONIC SYSTEMS
- SERVOMECHANISMS
- RELIABILITY

Resume may be forwarded to Mr. R. H. Byles

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All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin.

Stratoscope II

(CONTINUED FROM PAGE 41)

expenditures on a scale anything like those for defense.

There is probably some optimum combination of closed-loop servosystems and ground-commanded controls which would result in a happy compromise between reliability, cost, and flexibility. It has been our goal to find this optimum situation—in an operation so complex that the controls to be operated by radio number about 60 and the channels of real-time telemetry needed to make these adjustments number 28.

Our first move in specifying the components which form the command and telemetry systems consisted of making the chart, shown on page 40, that gives the relationship between the various commands and the periods during the flight when they would be operated. Each command is also weighted as to its effect on the flight if it were to fail. The chart shows that it will be necessary to perform a maximum of six commands simultaneously.

Since it is necessary for the operator to have a direct, proportional telemetry readback of his action to make an adjustment with an on-off command system successfully, available telemetry systems and how they might fit together with a command system was an additional factor in our design of the Stratoscope II command system. In the same fashion as in the command system, the chart on page 41 was made to show the number of simultaneous channels of information required and their relative importance to the flight. We found that the maximum number of simultaneous telemetry channels needed is 10.

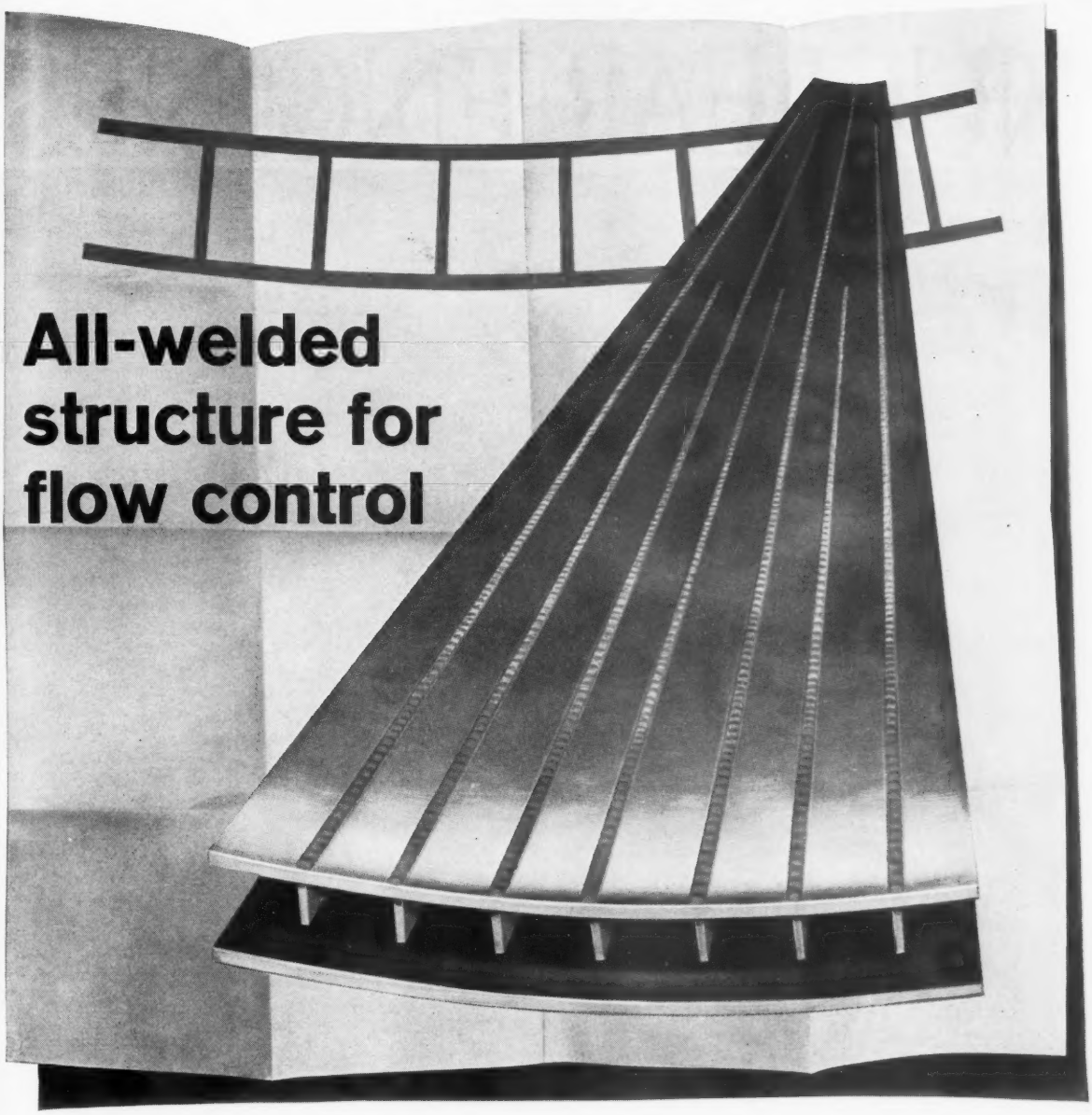
A highly reliable command link would consist of 120 separate radio transmitters and receivers, each with its own batteries and antenna, and a switching system to permit any of the 60 extra transmitter-receiver sets to substitute for any other, with a similar parallel telemetry system. Of course, such a system could not get beyond the concept stage. However, this kind of system represented a design goal, since it involves a minimum number of fallible elements in series. Initially, we had high hopes of utilizing a commercially available radio link used in control of oil refineries which made available 48 channels of on-off control per transmitter-receiver pair. But the environmental specifications for Stratoscope II soon discouraged this manufacturer. (The approach is still attractive, however.) We ultimately accepted RCA's proposal, which consisted of two Tiros I receivers modified to work at −65 C and two 20-tone audio decoder and control units operating a total of 40 relays.

This left a considerable gap between the radio-link capacity and the number of controls to be operated. It was obvious that some scheme which made multiple use of some of the modulating audio tones and their corresponding demodulating filters and control relays would be necessary. Having these design requirements in mind, we considered systems which made use of the 40 primary tones in various combinations (e.g., binary code) and time-sharing systems using one or more stepping switches.

The use of a large, multideck switch appeared to be a feasible solution to the problem, especially when the limited capacity of the subcarrier oscillator (FM/FM) type of telemetry link was considered. By having as many positions on the switch as there are phases to the flight, and as many decks as there are items which must be commanded or telemetered simultaneously, the gap between the capacities of the command link and the FM/FM telemetry could be readily bridged with the addition of just one additional component. Since this component could be made relatively large and heavy if necessary, it should be possible to make this switch very reliable.

As will be seen shortly, vestiges of this approach appear in the final configuration of the command and telemetry system. The first departure from this mode-switching idea was occasioned by our consideration of a telemetry system based on the sampling principle. We found already on the market several systems using what is essentially a high-speed electronic commutator to sample the various signals. The output of the commutator is transmitted in various ways (i.e., pulse-duration modulation, pulse-amplitude modulation, etc.) and then another electronic commutator on the ground, running in synchronism with the one in the air, is used to route the receiver output to displays for the operator. The lower cost and higher capacity of this type of telemetry system soon convinced us that it was the most feasible solution to our problem, even though such a system is less accurate than the FM/FM system we had first considered. The capacity of the sampling systems ranged from 60 to 90 channels, which was more than adequate for our needs. Thus, the need to switch the inputs to the telemetry for various phases of telescope operation disappeared.

Our telemetry specification was written on the basis of a commutative, or sampling, system. The successful



All-welded structure for flow control

Ordinary experience with metals cannot cope with the critical problems of fabricating this unique welded structure—ideally suited for the flow of liquids through contoured or tapered panels with variable flow areas or variable channel widths. The Budd Company has the know-how to solve the many difficulties involved. Further, the resistance welded fabricating technique used in this structure is applicable to a wide variety of materials and gages, and provides a joint that develops the strength and stability of the base material.

A pioneer for years in forming and welding, we are prepared to fabricate such structures today. Product Development Department, The Budd Company, Philadelphia 32, Pa.

PRODUCT Budd DEVELOPMENT

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NUCLEAR ENGINES

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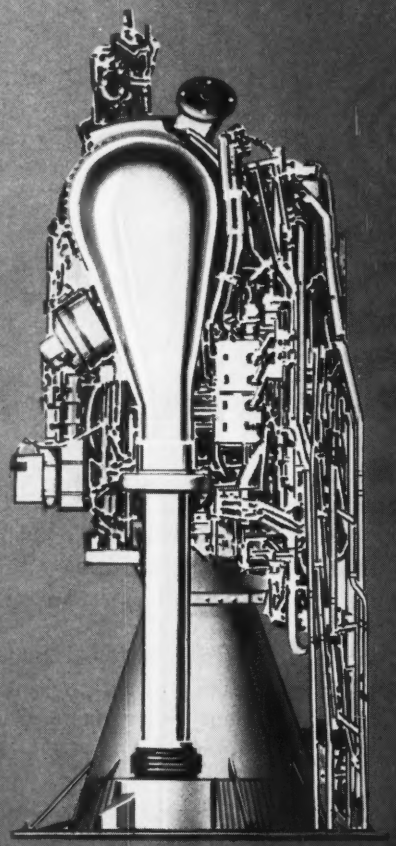
XLR99
Man-rated rocket engine for X-15. Pilot-safe, throttleable, liquid propelled... now carrying man to the fringes of outer space.



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World's largest solid rocket motor, reliability proven in 8 silo launches and full scale flight.

FOLLOW-THROUGH CAN DELIVER

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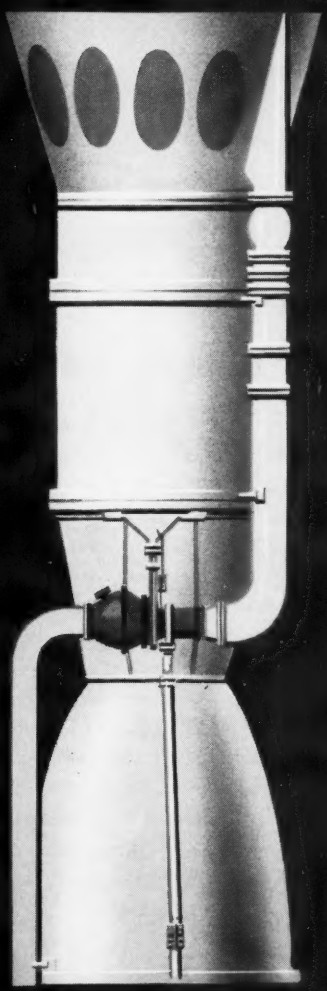
RELIABILITY IN NUCLEAR PROPULSION

NERVA
Conceptual nuclear rocket engine whose development is suited to the talents of **TALANT**—Thiokol, Allison, Linde And Nuclear Development Corp. of America Team.



The current state of the art in rocket propulsion presents a sound foundation for development of safe, reliable nuclear engines . . . powerplants needed in ultimate space exploration through manned flight.

Thiokol's contributions to propulsion progress are many and significant.

Performance of Thiokol systems in test and flight establishes the company's own position of technological leadership. The record underscores capability to manage and direct widely diversified industrial technologies to deliver the goods at minimum cost in time and dollars.

Successes of Minuteman, XLR99, Nike Zeus, Pershing and other missiles reflect major scientific and engineering breakthroughs for which Thiokol is responsible directly, or through its chosen sub-contractors. Breakthroughs in engine design, fuel configuration, new materials, and production methods achieved at Thiokol are milestones in rocketry's development.

Now, with TALANT, Thiokol is ready and able to meet the next challenge in man's conquest of space—nuclear rocket propulsion.

Nuclear Development Center

THIOKOL

CHEMICAL CORPORATION
Rockets Operations Center, Ogden, Utah

bidder was Sierra Research Corp. of Buffalo. The Sierra telemetry system provides 64 channels of information, and uses solid-state switching triggered by a binary logic, which is driven by a clock operating at 8 kc. Thus, the sampling rate is 125 times a second. The FM transmitter is modulated directly by the commutated signal, which ranges from +2 volts to −2 volts. Two complete systems including transmitters were purchased, the second system acting as a backup for the first. During flight, both systems, each having its own batteries, will be operating, but only one transmitter will be supplied plate voltage. In case of failure, a radio command will switch off the plate voltage to the failed system and switch on plate voltage to the standby system. Of the 64 channels, 28 are ground-decommutated and displayed on control console meters, and 30 (not decommutated) are displayed on an oscilloscope, permitting diagnostic monitoring of items about which the operators can take corrective action. Four channels are used internally by the telemetry equipment, and the remaining two channels are switched at 1-sec intervals to record battery voltages, temperatures, etc.

Having removed the necessity for a close tie-in between the command and telemetry systems, we once again concentrated on the design of the command system. The alternative to the mode-switch idea, mentioned previously, was a system which recognized various combinations of tones representing the commands. If a binary code were used, six simultaneous tone channels would be adequate to address any command; and with a necessity for six simultaneous operations, a total of only 36 tones would be needed. This appeared to be a good possibility, since the proposed RCA Tiros system operates with 20 tones on a receiver, and two receivers on different radio frequencies give a 40-tone capability.

Means for Command

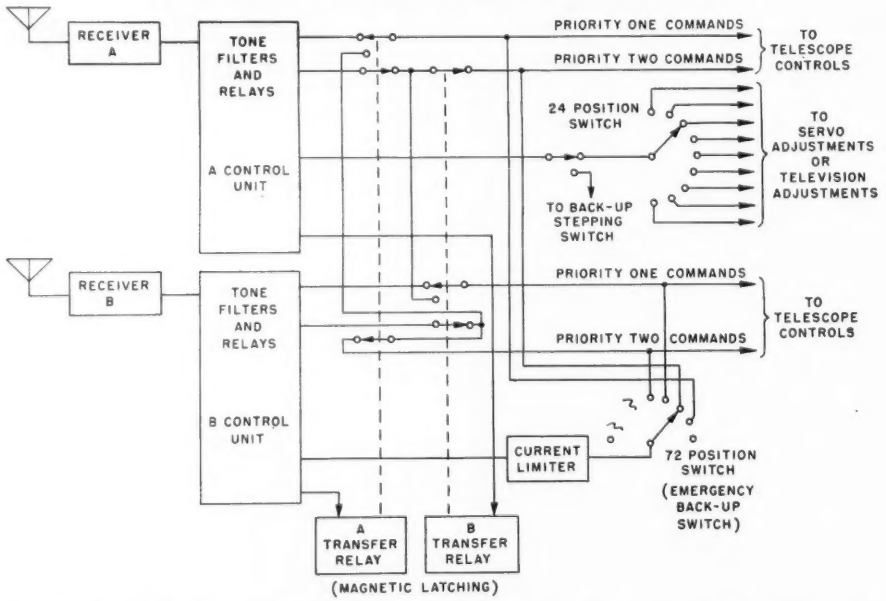
However, two factors tended to discourage this approach. One was the cost and anticipated difficulties of developing the decoding matrixes when compared to the ready availability of stepping switches which meet the environmental specifications. The second factor was the complexity inherent in providing a safe backup system to counter failures, and the large number of commands which would be made inoperative with the failure of a single tone.

With the stepping-switch approach, it is possible to control as many things as there are positions on the switch with just four tones: One to step the switch forward, one to step it backward, one to increase the adjustment thus addressed, and the last tone to decrease the value of the adjustment. A fifth tone will provide switching from one switch to a backup switch in case of failure of the first.

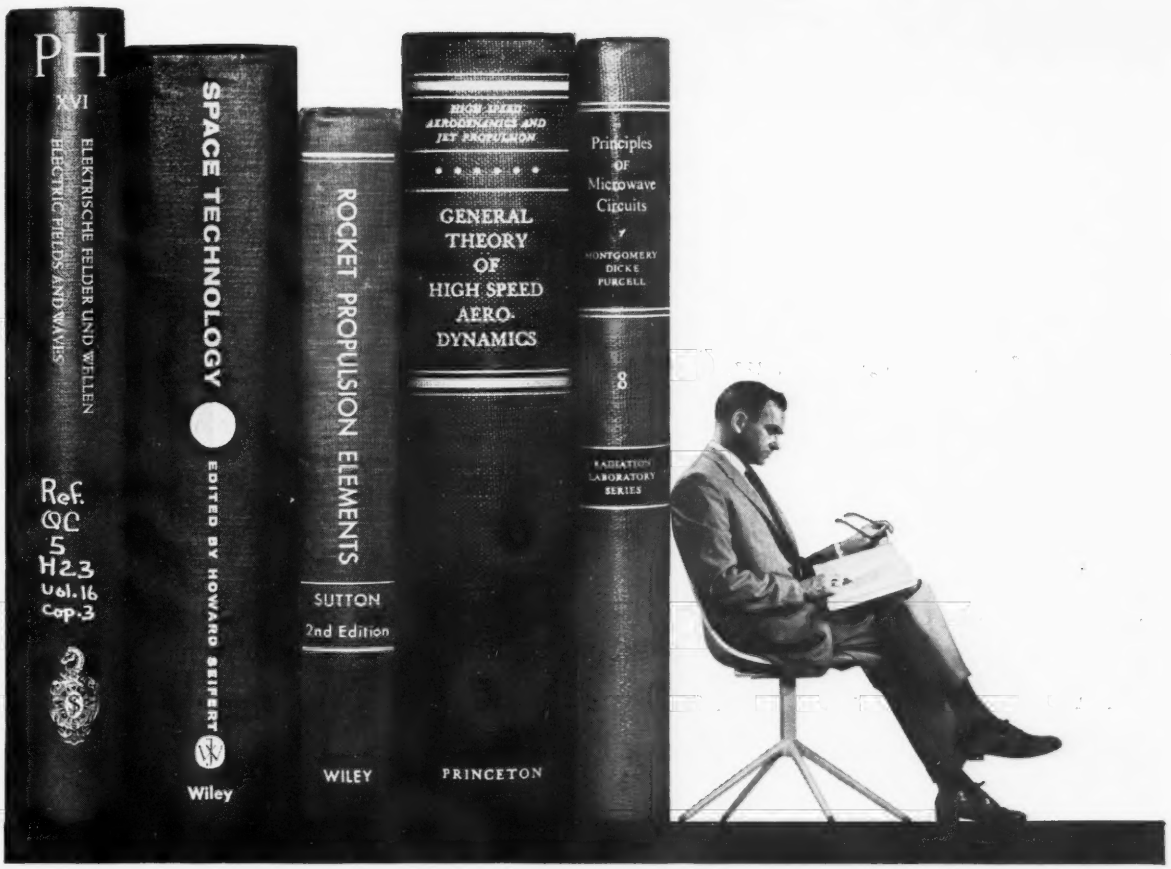
This is essentially the scheme which will be used in Stratoscope II. All of the adjustments which must be made to the servos between series of photographs are addressed via a set of bidirectional, 24-position stepping switches. The second switch provides insurance against the failure of the first. In addition, all of the television commands are reached through a second set of 24 position switches. All of the commands addressed via these stepping switches have a weight of 2 or higher in the chart on page 40. The corresponding telemetry readback for these commands is also switched by using another wafer on the switch.

Of the 40 original tones, this leaves 30 available for direct, unswitched commands. Since 35 commands are accounted for by the servo adjustments and television commands, there are only 24 commands to be served by the remaining 30 tones. These 24 commands have been divided into two groups: (a) Those which could cause a complete flight failure if they were to fail, and (b) those which would not absolutely jeopardize the success of a flight. In the first, and priority, group there were 12 commands. To provide a backup capability for these commands, half were put on each receiver. A switchover circuit was then designed which will transfer the ability to perform these commands from one receiver or con-

DIAGRAM OF STRATOSCOPE II COMMAND SYSTEM



This simplified block diagram shows the way in which each group of commands is handled. There are actually six stepping switches in the command system, two for the servo adjustments, two for the television adjustments, and two emergency backup switches.



scientists and engineers in a unique leadership role

The frontiers of space science and technology are being expanded at Aerospace Corporation. The scientists and engineers of this leadership organization are the critical civilian link uniting government and the scientific-industrial team developing space systems and advanced ballistic missiles. In providing broad scientific and technical leadership to every element of this team, they are engaged in a balanced program of activities spanning the spectrum from basic research and forward planning through general systems engineering. Included in the latter are technical supervision, integration and review of the engineering, development and test operations of industry to the extent necessary to assure achievement of system concept and objectives in an economical and timely manner. These people are privileged to view both the state-of-the-art and system development in their totality. Now more men of superior ability are needed: highly motivated scientists and engineers with demonstrated achievement, maturity, and judgment, beyond the norm. Such men are urged to contact Aerospace Corporation, Room 104, P. O. Box 95081, Los Angeles 45, California.

Organized in the public interest and dedicated to providing objective leadership in the advancement and application of space science and technology for the United States Government.

AEROSPACE CORPORATION

trol unit to the other in case of failure. Top-priority commands can thus displace commands of less importance. All of the top-priority commands may be operated via both receivers or via either one. The transfer circuitry was combined with the "turn off" switching, so that if the command to transfer control from both receivers is given, the command system is deactivated. The switching is accomplished through the use of magnetic latching relays, making it unnecessary to energize these relays continuously.

The Lesser Commands

To provide for commands of less priority—ones dropped in the transfers described above—a set of stepping switches having 72 positions was added. These switches can address any of the 60 commands, and require only four tones of the remaining five to do so. One tone is used to advance the switch, two to make the adjustment, and one to cause transfer from one switch to its backup. In addition to covering for commands which get dropped in the event of a receiver failure, these switches can substitute for a command which is disabled due to the failure of a command channel. The block diagram for the complete system is shown on page 102.

Initial flights of Stratoscope II are planned for late 1961. The adequacy of the design concepts described in this article will be proven then.

In the not so distant future, a telescope will be carried by a satellite beyond the radiation-absorbing layers surrounding the earth to obtain data in regions of the spectrum outside the visible. These long-duration flights will require the development of command and telemetry components which are an order of magnitude more flexible and reliable than those presently available to take advantage of the diversified research opportunities of the orbital space platform. ♦♦

Negative-Ion Studies Undertaken at NBS

Studies of the photodetachment of electrons from negative ions are being made at the National Bureau of Standards, with attention focused on the cross sections of negative atomic hydrogen ions and negative atomic and molecular oxygen ions. The interactions under study are important in ionospheric phenomena and thermodynamics of hot gases.

Original painting by Emil Bisttram, Taos, N. M.

Tangible returns FROM PURE RESEARCH have been gigantic

Pure research, stimulated by curiosity and the satisfaction of accomplishment, has given us knowledge and understanding of many of the phenomena of our world. The rapid exploitation of such discoveries, especially in this century, has resulted in our present amazing technology. These tangible returns from pure research have been gigantic. From the brilliant investigations of nineteenth-century physicists on the nature of electric and magnetic fields have developed electric power, electronics, radio, television. Examples from the past are countless. Even in recent decades we have witnessed enormous application of discoveries merely incidental to research in elementary-particle physics: isotopes, nuclear fission and power, medical therapy with high-energy beams, a step toward controlled thermonuclear power — a list that continues to grow rapidly.
The practical results that must derive from continued exploration . . . cannot be guessed. If the past is a guide they will be numerous and fantastic. The one thing that we have learned to expect from nature is to be surprised.

Excerpt: A special Report of the U.S. Atomic Energy Commission, January 1961 entitled, "Atomic Energy Research in the Life and Physical Sciences, 1960."

For employment information write
Personnel Director, Division 61-43

los alamos
scientific laboratory
OF THE UNIVERSITY OF CALIFORNIA
LOS ALAMOS, NEW MEXICO

He solved this puzzle by taking it apart!

Like oil and water, extreme precision and "complete" mobility resist combination in tracking radar antennas. Designing for one of these characteristics "automatically" precludes the other. *That* was this AMF Engineer's puzzle—to put *both* precision *and* mobility in an antenna for duty with the Marine Corps.

He solved the puzzle, literally, by taking apart the solution—AMF's TPQ-10 antenna—into 10 rugged, portable, submersible, precision-fabricated packages. TPQ-10 is designed for helicopter transport. Each component can be dropped in water; it will come up for more. The packaged antenna on its pallet can be dropped on land from 3 feet without impairing precision.

Each component can be *picked* up—the largest weighs 425 lbs.—and can be handled by 3 men. A crew of 6 can put TPQ-10 together in 20 minutes with one standard wrench.

Among the design innovations that solved the puzzle is a "piggyback" gear arrangement that puts both azimuth and elevation drives in one package. Result: almost half the parts and weight of separate components. Precision fabrication is typified by the reflector arms, held to a .005" deviation over 45 inches!

(For unclassified information on early warning and radar antenna systems, write Dept. CS 1, address below.)

Single Command Concept

Solving puzzles with next-to-impossible conditions is AMF's business. AMF's imagination and skills are organized in a single operational unit offering a wide range of engineering and production capabilities. It accepts assignments at any stage from concept through development, production and service training, and completes them faster... in

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n engineering and manufacturing AMF has ingenuity you can use . . . AMERICAN MACHINE & FOUNDRY COMPANY

Rocket Weapon for Foot Soldiers

This neat little rocket-powered antitank grenade launches from the disposable container held by Maj. Gen. John A. Barclay, deputy commanding general of the Army Ordnance Missile Command, managing agency for the new weapon. Project engineers for the weapon Raymond W. Turner, left, of ABMA and Earl R. Edmonson of ARGMA look pleased with their work. The Army reports the little missile highly effective against a variety of tanks, armored vehicles, and field fortifications. Hesse-Eastern Div. of Flightex Fabrics Inc. is prime contractor for the weapon system.

Transit Program Results

(CONTINUED FROM PAGE 31)

Transit satellites as a special communication link. Specifically, after the orbit is determined on the ground, a parametric description of this orbit is transmitted to the satellite, recorded in a memory system contained in the satellite, and subsequently broadcast at regular (2-min) intervals. Thus, the user receives a description of the orbit of the satellite simultaneously with his measurement of the doppler shift. By this means it is possible to improve the description of the orbit frequently. In fact, it is intended to insert a current or updated description every 12 hr.

While this description makes Transit sound relatively simple, it can perhaps be imagined that there were a number of formidable technical difficulties to be overcome before a practical operating system could be designed in detail. This article presents some of these problems and the progress that has been made toward their solution by the Transit launchings to date.

To the time of this writing there have been three Transit satellites placed in orbit out of a total of five attempts. A few of the significant parameters of these three satellites are displayed on page 31.

It will be noticed that, although we have been moderately fortunate in getting satellites placed into orbit, we have been less fortunate in the orbits achieved. None of the three orbits has approached very closely the circularity that was desired, and two of the three have had perigee at so low an altitude that atmospheric drag very seriously affected the calculation of the orbit. The last satellite, Transit 3-B, had perigee so low that it had a life of only 36 days, and it re-entered the atmosphere and was consumed on March 30.

There have also been a few equipment failures in the satellites themselves. A temperature-sensitive switch, included in Transit 1-B to protect the storage battery from overcharge, opened improperly and permanently on or about July 11, 1960, and the satellite ceased radiating due to loss of power. Thus Transit 1-B had a useful radiating life of 89 days.

The same switch malfunctioned in Transit 2-A. In this case a command bypass of the switch had been incorporated and was actuated to prolong the life of the satellite. However, bypassing this switch removed the overcharge protection, which was the reason for incorporating the switch, and the storage battery was destroyed by overcharge during the period Oct. 28 to Nov. 14, 1960, while the satellite was in the sunlight at all times and correspondingly receiving maximum power from its solar cells. Since the loss of the storage battery, the Transit 2-A radiates only when it is in sunlight, receiving power directly from the solar cells. With this intermittent operation, the stability of the oscillators is, of course, not up to the level that obtained during the period of proper, full-time operation. Transit 3-B operated fully throughout its short life.

Operational Concept Feasible

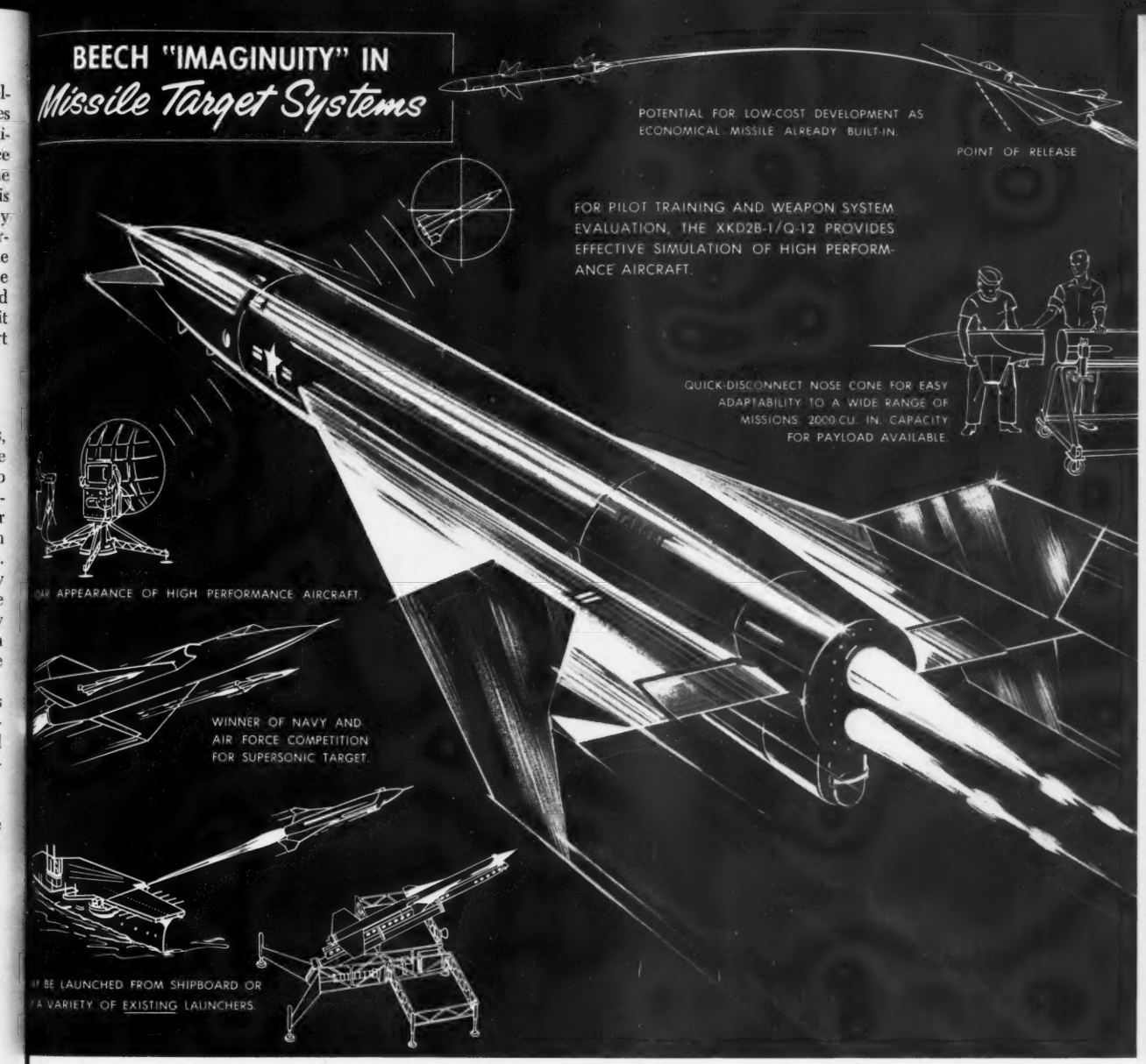
In spite of these various limitations, it has been possible, with the three satellites placed in orbit to date, to demonstrate rather remarkable progress toward overcoming the major technical obstacles that lay in the path of establishing an operational system. In particular, there are no longer any questions about the feasibility of the operational concept, and it is now possible to specify a detailed design with confidence that it will meet the requirements.

In what follows, the various areas that were expected to provide technical difficulties will be discussed, and the state of progress toward their solution described.

Stability of the Satellite Oscillator. This was initially expected to be one of the difficult problems. The fact is that, while the doppler shift does determine the relative geometry of the satellite orbit and receiving station, it requires a very accurate measure of the doppler shift to obtain a good measure of this relative geometry. Although there is no simple relationship between an error in doppler measurement and the corresponding position error, a crude rule-of-thumb relationship, usually valid within an order of magnitude, is given by the statement that an error of 1 cps in doppler gives an error of 1 mi in position if the transmitter frequency is 100 mcps. Since, in the Transit system, any variation in transmitted frequency during the time of a pass will be erroneously ascribed to the doppler effect, it is clear that a frequency drift of only 1 part in 10^8 during the time of a pass can result in a serious error in position determination.

It is true that many oscillators with stability better by orders of magnitude than 1 part in 10^8 had been built before the start of the Transit program, but these were generally rather elaborate devices including proportional-heating ovens to control the crystal frequency and were not suitable for use in small and simple satellites.

Actually, as can be seen from the table on page 31, the oscillator sta-


BEECH "IMAGINUITY" IN
Missile Target Systems
POTENTIAL FOR LOW-COST DEVELOPMENT AS ECONOMICAL MISSILE ALREADY BUILT-IN.
POINT OF RELEASE
FOR PILOT TRAINING AND WEAPON SYSTEM EVALUATION, THE XKD2B-1/Q-12 PROVIDES EFFECTIVE SIMULATION OF HIGH PERFORMANCE AIRCRAFT.
QUICK-DISCONNECT NOSE CONE FOR EASY ADAPTABILITY TO A WIDE RANGE OF MISSIONS. 2000 CU. IN. CAPACITY FOR PAYLOAD AVAILABLE.
APPEARANCE OF HIGH PERFORMANCE AIRCRAFT.
WINNER OF NAVY AND AIR FORCE COMPETITION FOR SUPERSONIC TARGET.
BE LAUNCHED FROM SHIPBOARD OR
A VARIETY OF EXISTING LAUNCHERS.

Navy XKD2B-1 and Air Force Q-12 . . . . .

Mach 2 target system developed by Beech also has promising potential as economical missile system

Born of Beech experience in many fields of modern weapon development, the Navy XKD2B-1 and Air Force Q-12 meets the need for a target system capable of simulating the speed, altitude and target characteristics of high performance aircraft. It makes possible, at low cost, realistic pilot training and effective evaluation of advanced weapons systems. Designed to score hits or misses. It has a pre-programmed guidance system, and can operate at altitudes from 1,000 to 70,000 feet.

In addition to its target capabilities, XKD2B-1 or Q-12 has great potential for further development as an economical missile system. It can carry a substantial payload to fulfill a wide range of future missions.

Beech *Aerospace Division*

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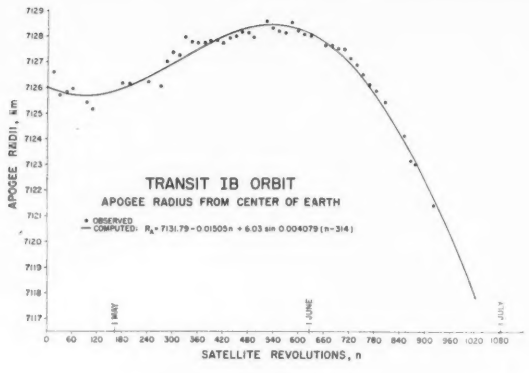
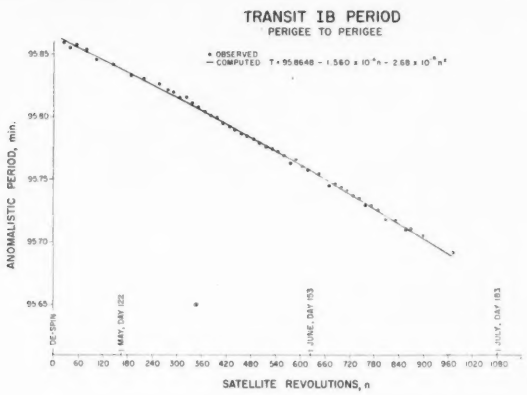
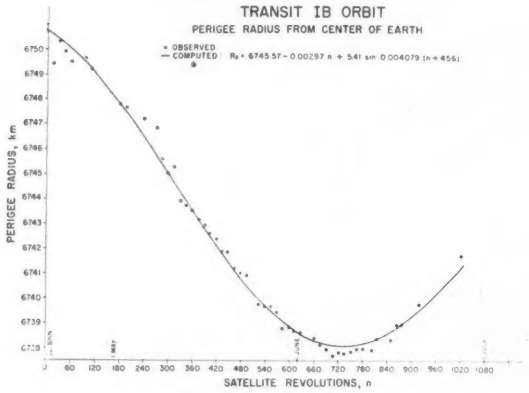
Beech Aerospace Division projects include R&D on manned aircraft; missile target and reconnaissance systems; complete missile systems; electronic guidance systems; programs pertaining to liquid hydrogen propellants and cryogenic tankage systems; environmental testing of missile systems and components; and GSE.

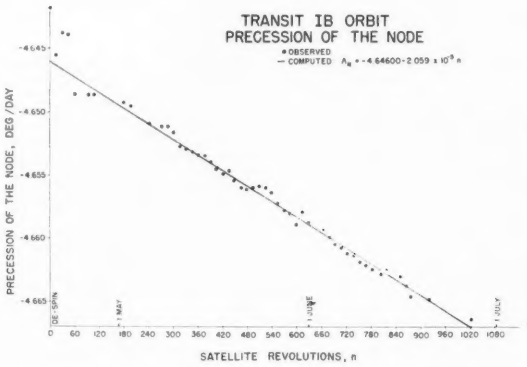
May we help you? Write, wire or phone Roy H. McGregor, Manager—Contract Administration, Beech Aircraft Corp., Wichita 1, Kansas—or nearest Area Office.

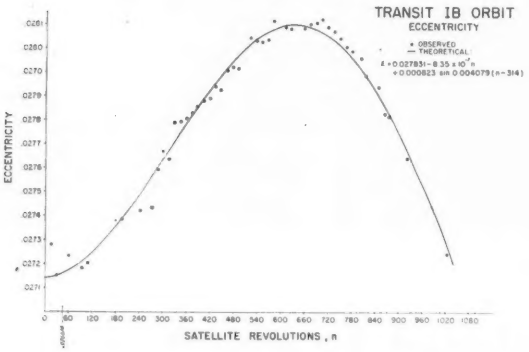
Transit Tracking Results

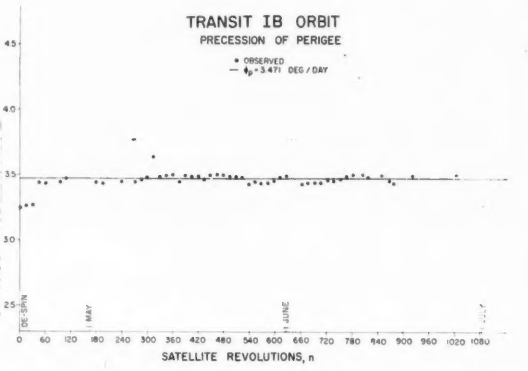


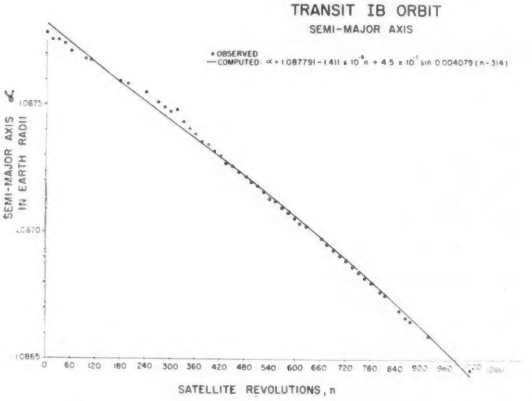

TRANSIT IB PERIOD
PERIGEE TO PERIGEE
• OBSERVED
— COMPUTED: $T = 95.8648 - 1.560 \times 10^{-4} n - 2.68 \times 10^{-8} n^2$
ANOMALISTIC PERIOD, min.
SATELLITE REVOLUTIONS, n
DE-SPIN
MAY, DAY 122
1 JUNE, DAY 153
1 JULY, DAY 183

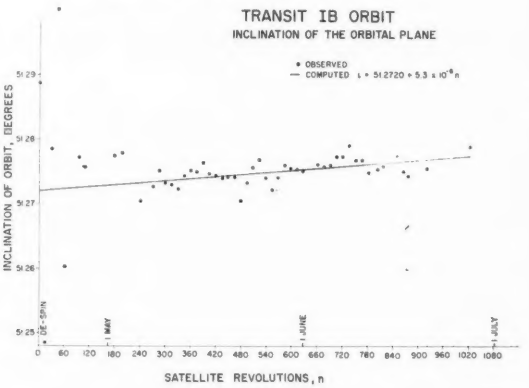









TRANSIT IB ORBIT
SEMI-MAJOR AXIS
• OBSERVED
— COMPUTED: $\alpha = 1.087791 - 1.411 \times 10^{-6} n + 4.5 \times 10^{-7} \sin 0.004079(n-314)$
SEMI-MAJOR AXIS IN EARTH RADII
SATELLITE REVOLUTIONS, n



bility has not proved a very difficult problem. A rather elaborate temperature isolation of the crystal from external heat sources, taking advantage of the superb vacuum available in the operating environment, has kept the rate of change of frequency due to temperature change at the crystal within acceptable limits, and careful circuit design has minimized other sources of frequency change. Other techniques used include long burn-in of all crystals and selection of crystals on the basis of stability after this burn-in period. While techniques for still further improvement are under investigation, the presently achieved stabilities are good enough to meet the program objectives.

Refraction by the Ionosphere. The doppler shift exhibited in the reception of a transmission from an earth satellite is not strictly proportional to the rate of change of the true slant range, but rather is proportional to the rate of change of the transmission path length. If, as is normally the case, the satellite is above the ionosphere, then the transmission path is not a straight line joining the transmitter and receiver, but instead is some longer curved (or bent) path due to the refraction effect of the ionosphere. Hence, for a precision analysis of the doppler shift, account must be taken ot the effect of this ionospheric refraction on the doppler.

Ionospheric Effects

A rough model of the ionosphere indicates that the effect of ionospheric refraction on the doppler shift should be inversely proportional to the square of the transmitter frequency. This suggests that refraction can be made negligible by going to a sufficiently high frequency. And, indeed, at microwave frequencies (and above) the ionosphere has a negligible effect on the received doppler shift. Unfortunately the use of microwave frequencies would require the use of either large directional antennas for reception or very high transmitter powers.

The first solution would be undesirable for many potential users of Transit (e.g., submarines or aircraft) and the second is unavailable with small, easily launched satellites. Accordingly, it has been considered wise to restrict the Transit frequencies to the range (hundreds of megacycles) where solid-state amplifiers are usable. In this range, ionospheric refraction cannot be neglected with high accuracy. The technique used in Transit is to transmit a pair of harmonically related (coherent) frequencies rather than a single frequency. From the doppler shift obtained on

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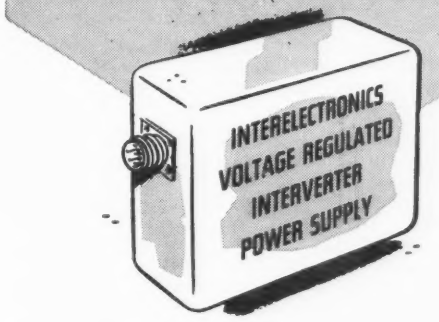

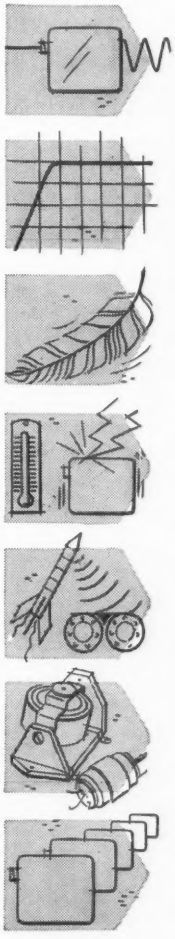

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Now in use in major missiles, powering telemeter transmitters, radar beacons, electronic equipment. Single and polyphase units now power airborne and marine missile gyros, synchros, servos, magnetic amplifiers.

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each of these frequencies, it is possible to obtain a measure of the integrated electron density between the transmitter and the receiver and then to develop a good estimate of the doppler shift that would have been measured in the absence of the ionosphere. It is this so-called refraction-corrected doppler, or vacuum doppler, that is used in the Transit program for orbit determinations and precise navigational fixes. Actually, the generation of the vacuum doppler from the individual doppler shifts at the two harmonically related frequencies is accomplished by a relatively simple analog computer, which would yield a precisely correct answer if the $1/(\text{freq})^2$ refraction law were precisely correct.

Results to date indicate that at mid-latitudes or lower the refraction correction based on the $1/(\text{freq})^2$ assumption is sufficiently accurate to meet the Transit program goals even in times of magnetic-storm activity. However, there is need to explore further the refraction effect at high latitude during heavy auroral activity to determine if this correction remains sufficiently accurate in these most severe conditions. Considerable effort in this area is planned for the next year.

Transmission of the Orbit Parameters. In principle the transmission of the orbit parameters from the satellite poses a relatively easy communication problem and can be accomplished straightforwardly in a number of ways. Practically speaking, it is desirable to develop a means which poses the least increase in complexity or power on the part of the satellite equipment and the least special equipment for reception on the part of the navigator. To this end, a system has been developed in which the orbit parameters are transmitted in binary notation (zeros and ones) coded as a phase modulation of the basic transmission which is used to generate the doppler shift. A specific modulation (60-deg phase advance followed by a 60-deg phase retard) is used which does not interfere with the ability to measure the doppler shift with precision. The use of this approach avoids the need for an extra transmitter in the satellite or an extra receiver in the ground equipment. This system for the distribution of data by means of a satellite link was incorporated, for the first time, in the short-lived Transit 3-B and operated perfectly throughout its life.

Time Synchronization. Since the time at which orbit parameters are transmitted is controlled by a satellite clock based on the same stable oscillator that controls the two basic frequencies, it is clear that the time of reception of orbit parameters can be used as a time signal by the ground equipment. This makes the Transit system completely self-contained, independent of any other time source, such as WWV.

Actually, because of the short, well-defined transmission path for the Transit line-of-sight frequencies and the excellent knowledge of satellite position, the time signals available from Transit will be more accurate than those available from WWV in most areas of the world. In fact, a precision of 100 microsec should be readily available. A system has been developed for including along with the orbit-parameter transmission a special word ("Barker" word) which serves the purposes of a start-of-message and time-synchronization signal. This system also was successfully tested in Transit 3-B.

Tracking Accuracy. When the Transit program was first proposed, the most serious technical questions raised concerned the feasibility of tracking the satellites with sufficient accuracy. Obviously, to determine your position on earth by reference to the position of a satellite, it is necessary that the position of the satellite, at a given time, be known to higher accuracy than the accuracy with which your own position is to be determined. At the time the initial Transit program proposal was being considered, typical satellite tracking or prediction errors ranged from 5 mi to as much as 50 mi. There was a wide spread belief among even well-informed people that there were mysterious or at least unpredictable forces of large magnitude acting on satellites which would for years prevent orbit prediction with an accuracy of better than a number of miles.

Fortunately, most of the difficulties of that period were a result of poor measurements rather than of a reflection of basic unknowns. It is true that there were, and still are, areas of ignorance concerning the precise formulation of the forces acting on a near-earth satellite (for example, the proper description of the earth's gravitational field is not too well known), but the effect of these uncertainties on the trajectory is one- or two-tenths of a mile rather than a number of miles.

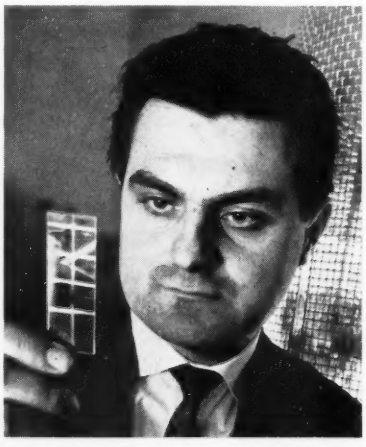
The fact that present knowledge of the forces acting on a satellite is sufficiently accurate to enable tracking and short-term (12-hr) prediction of satellite position to an accuracy of a few tenths of a mile has been shown conclusively by our tracking experience with Transit 1-B and Transit 2-A.

Determining Orbits

One way to judge the accuracy with which orbit determinations are made is simply by observing the consistency of the determination from one day to the next. In the Transit program, an orbit is determined for each day based solely on the data obtained on that day, so that each determination is totally independent of all preceding data. Hence, the day-to-day consistency of orbit parameters is a very good indication of the precision of the system. The determination of orbit parameters through most of the radiating life of Transit 1-B is given in the graphs on page 108. It will be seen that the first four or five points show a much larger scatter than the subsequent points (particularly in the last three graphs on page 108). This results from the fact that for this initial period the satellite was still spinning and the spin caused a modulation on reception that was interpreted by the ground equipment as a change in the doppler frequency. After this initial period the satellite was despun using

Another Link in the Microminiaturization Art

Physicist Franz Huber of Republic Aviation holds a thin-film tunnel diode capable of working at room temperature. Devised by Dr. Huber and his associates, the new diode was formed by capturing titanium vapor on glass strip under a vacuum, to form a film less than 1 millionth of an inch thick. Previous developments in function to the tunnel diode but requiring near liquid-helium temperatures to operate. Diodes that operate at ambient temperatures should advance the microminiaturization art greatly, and speed the development of compact space-vehicle computers, navigational units, and other instrumentation.

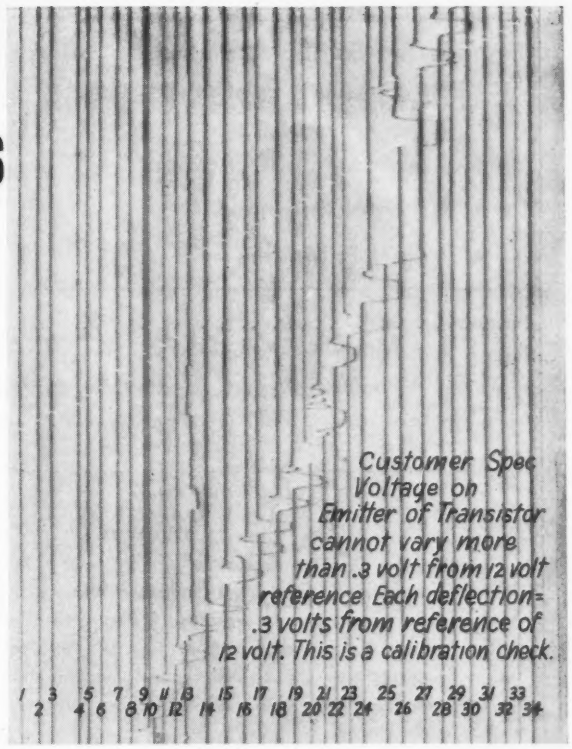


The little plate holds an experimental thin-film diode capable of operating at room temperature.

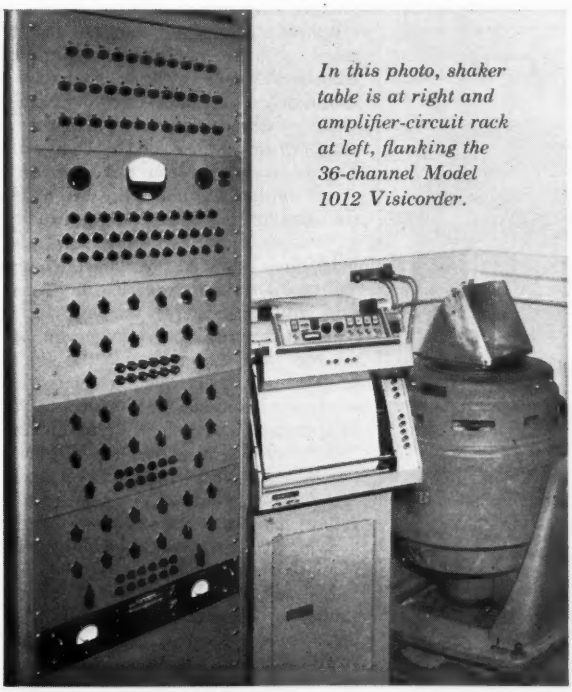
The VISICORDER records transistor torture

Transistors often have to work under incredibly severe environmental conditions. Production-testing them gave engineers at Honeywell's Semiconductor Division a chance to exploit the great versatility of the 36-channel Visicorder oscillograph Model 1012.

A certain order of transistors had to withstand vibrations of 10G at 10 to 2,000 cps without failing during the test or as a result of it. A standard test had been to measure the transistor's performance, next subject it to non-active vibration (not in any circuit), and then re-measure. This approach was obviously deficient as it did not reveal *operating* characteristics during test, nor did it disclose *intermittent*-type failures.


Customer Spec
Voltage on
Emitter of Transistor
cannot vary more
than .3 volt from 12 volt
reference. Each deflection=
.3 volts from reference of
12 volt. This is a calibration check.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34

Unretouched record of vibration test on 36 transistors, each active in its own circuit during test.



In this photo, shaker table is at right and amplifier-circuit rack at left, flanking the 36-channel Model 1012 Visicorder.

The customer's quality requirements were stringent (AQL = .4%) and the large test sample required ruled out the use of an oscilloscope. The 3-hour test would have made a battery of scopes and operators necessary; transient defects would be missed due to eyestrain, fatigue, etc.

The Model 1012 Visicorder was chosen for the task as it simultaneously measures and records 36 channels of test information throughout the test period. The Visicorder instantly and directly records transients, no matter how random.

A Visicorder record like this is always a welcome supplement to your test data—your customer will be able to read it quickly and with full understanding. And it is a *permanent* record which *he* can show to *his* customer, if necessary.

For further information on how Visicorders can help to solve your instrumentation problems, contact your nearest Honeywell sales office without delay. Or write for Catalogs HC 906, 1012, 1108 and 1406, to:

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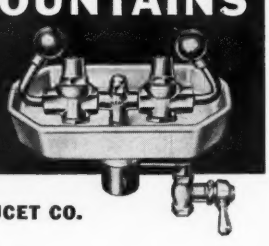

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the yo-yo technique, (see "The Transit Program" in the June 1960 *Astronautics*), and the data became much cleaner. It can be seen, particularly from the first two graphs on page 108, after the spinning period the scatter of the day-to-day determinations of orbit parameters is generally well within one-half of a kilometer, or one-quarter of a mile.

The nature of the long-term variation of the orbit parameters, particularly as seen in the first column of graphs on page 108, is quite interesting. Both apogee and perigee exhibit a linear decrease with a sine-wave oscillation superimposed. This oscillation has an amplitude of about 6 km, and its period is the period of precession of perigee. Thus the sine-wave terms in the formulas given for apogee and perigee are zero when perigee occurs at the equator, and reach their extreme values when perigee reaches the extremes of latitude. The linear decrease of apogee and perigee is due, of course, to drag. The effect of drag on apogee is five times as great as the effect on perigee. This is reasonable, since most of the drag occurs as the satellite goes through perigee. This results in a velocity decrease at perigee, so that the satellite does not swing out quite as far at apogee the next time around.

The sine-wave oscillation in the amplitude of apogee and perigee, in phase with the precession of perigee, clearly shows that the orbit behaves differently depending on whether perigee occurs in the northern or southern hemisphere. This is a striking illustration of the existence of a north-south dissymmetry in the earth—the famous "pear-shaped" term in the expansion of the earth's gravitational field, first deduced by O'Keefe from Vanguard data. From the first, second, and third graphs on page 108 it is of course possible to confirm quantitatively the value of J_3, the "pear shaped" coefficient in the expansion of the gravitational field of the earth in spherical harmonics. In fact, from this data for Transit 1-B, together with similar data for Transit 2-A, R. R. Newton has improved on the value for J_3 and has also obtained values for J_5 and J_7, the next two odd-order coefficients beyond J_3.

Not all of the long-term effects shown in the graphs on page 108 are understood. For example, the very small but clearly significant increase in the inclination of the orbit through May and June has not been explained to date.

The day-to-day consistency of the Kepler orbit elements is not the best way of judging the accuracy of the tracking, and could indeed be misleading, since there has been perforce

some smoothing of data involved in the very act of describing the orbit by means of Kepler elements. Actually, the true orbit, obtained by a numerical integration of the full equations of motion, departs from a Keplerian ellipse (even with allowance for precession of perigee and the line of nodes) by one- or two-tenths of a mile. Obviously the "smoothness" of parameters which, at best, can only approximately describe the orbit cannot accurately indicate the precision of the system.

Tracking Accuracy

A somewhat better indication of the accuracy of Transit tracking is obtained by a sort of closed-loop consistency calculation. To accomplish this consistency check, the data for one particular pass at one station are held in reserve and the orbit is determined by the remaining passes during a particular time period. Then, using this orbit and the reserved single-pass data, the location of the ground station is computed—just as would be done in a typical navigation fix. The result of this position determination is compared with the known ground-station location and the assumption is made that the error in satellite position is no greater than this resulting error in station location (actually it should be appreciably less, on the average, since there would be some error in station location even with a perfectly known orbit). Large numbers of these "closed-loop" calculations have been performed based on data from Transit 2-A, and the resulting sigma is well under $^1/_4$ mi.

It might be thought that these calculations are a direct test of the ability to perform navigation fixes by Transit. Unfortunately this is not quite so. For to use Transit for navigation in the practical operating system, it is necessary to base the calculation on an orbit determined previous to the time of the navigation fix (based on prior data). In other words, the practical use of Transit for navigation always involves orbit extrapolation. This extrapolation process introduces a further error, which obviously depends on the state of knowledge of the forces acting on the satellite, and in particular on the knowledge of the gravitational field. Calculations similar to those described in the preceding paragraph, but where the data used for the position determination were obtained a day later than those used for the orbit determination (thus requiring a full day orbit extrapolation), indicate that the resulting error in position determination is now about $^1/_2$ mi. Extending the orbit extrapolation further —for example, to four days—increases the error to about 3 mi, with the error occurring mostly along the satellite track.

All of these methods estimating the error of tracking by Transit techniques still leave a small uncertainty about the absolute precision, since they are only self-consistency checks, and it is possible to imagine some form of consistent bias that cancels out when you "close the loop." For example, all the consistency checks cited could remain valid for a system that consistently tracks a phantom point 5 mi ahead of the real satellite in the same orbit. This would not matter for navigation, but would introduce real trouble when one attempted to use the results to deduce geodetic consequences.

Fortunately, a completely independent check has been made possible by the availability of optical sighting data of reasonable precision reduced by the Smithsonian Astrophysical Observatory. The data for sightings of Transit 1-B from optical stations in the United States agree with Transit determinations of the satellite position to about $^1/_4$ mi. Optical sightings elsewhere in the world disagree somewhat more (sometimes 1 to $1^1/_2$ mi) because of uncertainties in the absolute location of these overseas sites relative to the center of the earth.

The precision of measurement now possible with Transit techniques is quite good. But both the determination of orbit during a 1-day period and the ability to extrapolate the orbit for 1 day are presently limited (to a few tenths of a mile in each case) by inaccuracies in the present model of the force field (gravitational field, drag, etc.). On a worldwide basis, there are further difficulties introduced by the unavailability of sufficiently accurate datum ties.

Meeting the ultimate program goals for Transit thus requires considerable improvement in the present knowledge of these factors (roughly the shape and mass distribution of the earth). This is the primary remaining development challenge of the Transit program.

Fortunately, the Transit system itself provides one of the most powerful tools available for accomplishing these goals. Furthermore, considerable effort using both Transit and other techniques is planned, or already underway, not only in the Transit program, but by many other programs in the Army, Navy, Air Force, and NASA. It is clear that the next year or two will see tremendous advances in these basic problems of geodesy.

Other Problems. While our discussion has covered the major technical aspects of the Transit program, there have been, of course, a host of detailed technical or practical operational problems that required solution. Some of

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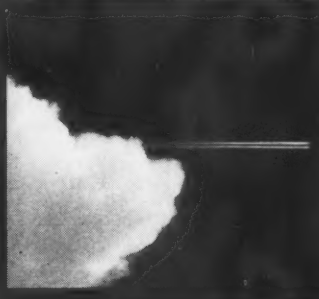

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these solutions are sufficiently novel to merit comment. The problem of despinning satellites, alluded to above, is one such example. Transit 1-B used the so-called yo-yo, devised independently by APL and JPL. Subsequently it was found the same objective could be accomplished even more simply, without moving parts, by using magnetic damping in the earth's magnetic field. A combination of two phenomena, hysteresis loss and induced current loss, provides effective despin.

A practical problem that has been solved quite effectively is that of making full use of the capabilities of the launch vehicles when these exceed the requirements of a specific payload. The solution adopted is to fire a multiplicity of payloads in a pickaback configuration. This technique has worked quite well. It is true there has been one failure to separate (Transit 3-B) but this was caused by a simple programmer malfunction during the launch phase and not by any difficulties inherent in the multi-payload technique.

In conclusion, it may be stated that the Transit program not only will provide a very useful practical application of earth satellites to the solution of a serious terrestrial problem (navigation) but also that its development is making many important contributions to space technology and earth science.

Suggested Additional Reading
Proceedings of the IRE, September 1960. ♦♦

Langley Hydrodynamic Facilities Reactivated

The Navy Dept. has reactivated hydrodynamic research facilities located at NASA's Langley Research Center, with an initial staffing of 15. The mission of the newly established "High-Speed Phenomena Div." will be to conduct research and development programs on hydrofoils, air-cushion vehicles, hydro-skis, planing catamarans, STOL seaplanes, torpedoes, and underwater rockets. This move followed NASA termination of many programs begun under the NACA. NASA continues investigation at Langley of ditching and water landing of space vehicles.

CARDE and ARGMA Jointly Studying Missile Defense

The Army Rocket and Guided Missile Agency, Redstone Arsenal, Ala., has joined with the Canadian Armament Research and Development Establishment, Valcartier, Canada, to study ballistic-missile-defense problems.

Developed by the Sperry Semiconductor Division, Norwalk, Connecticut, this logical element is currently being utilized at Remington Rand Univac for use in future computers. It is a Sheffer Stroke circuit, using semiconductor integrated networks (SEMI-NETS*), and is fabricated from a single block of semiconductor material, using precisely controlled processes of oxide masking and solid state diffusion.
Photo at left is actual size.

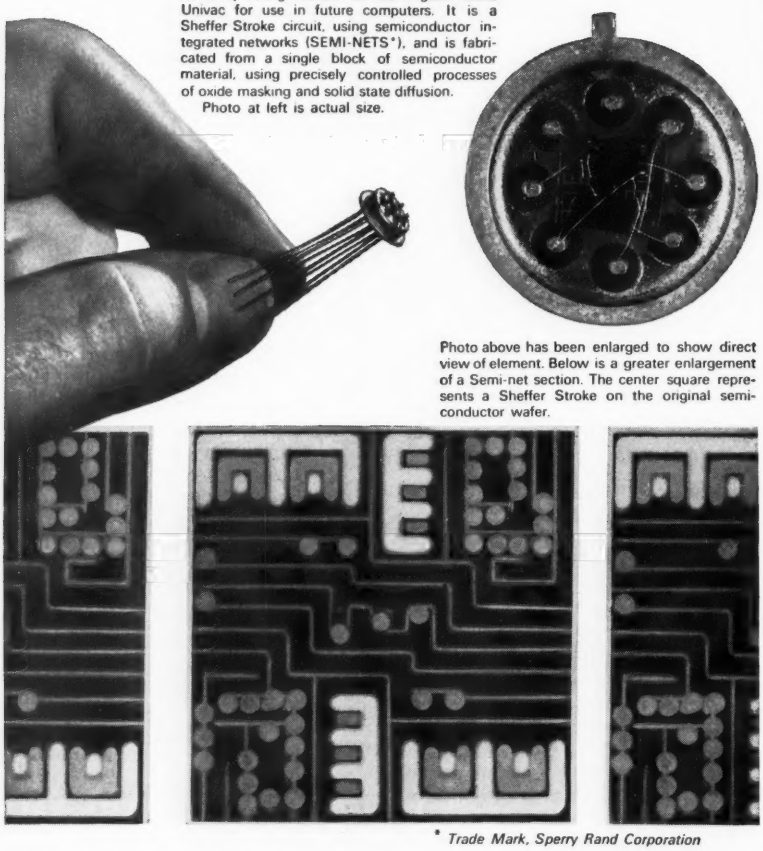

Photo above has been enlarged to show direct view of element. Below is a greater enlargement of a Semi-net section. The center square represents a Sheffer Stroke on the original semiconductor wafer.

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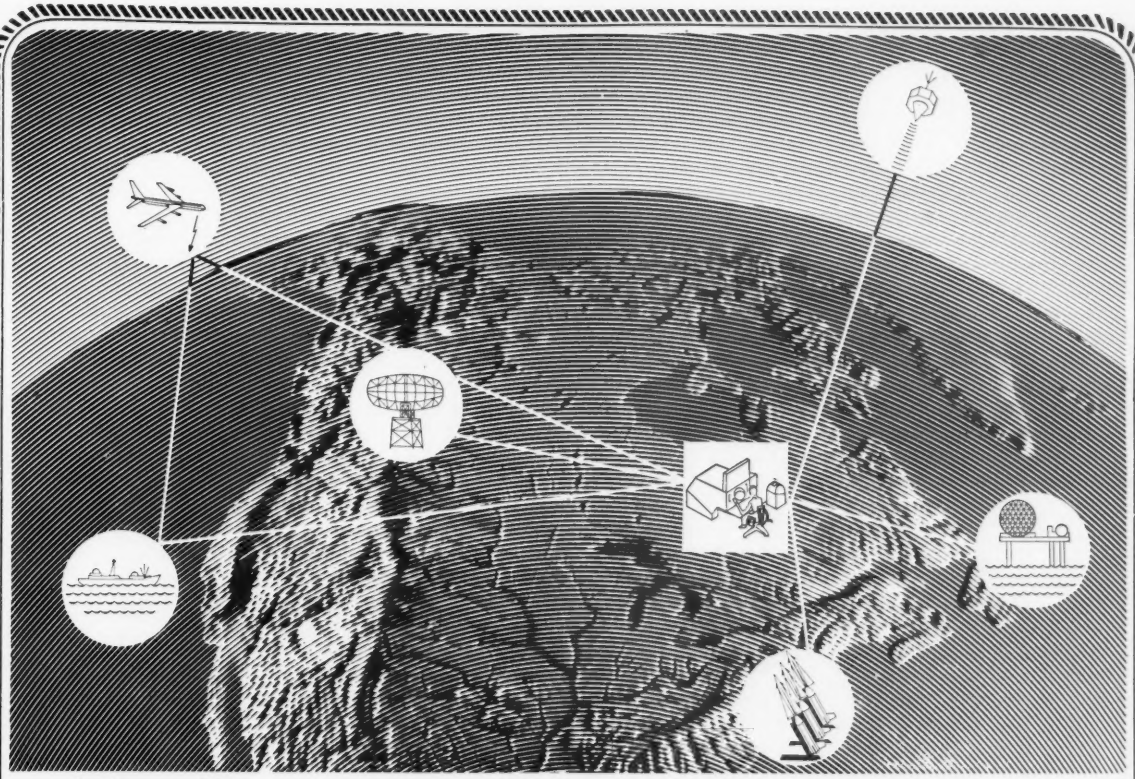

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(CONTINUED FROM PAGE 43)

either the primary guidance subsystem or to the display subsystem. Such data might include ground-derived position, guidance checking, steering instructions, or energy-management instructions. For the unpiloted glider, command data may also include destruct commands, originated by range-safety or supervisory control.

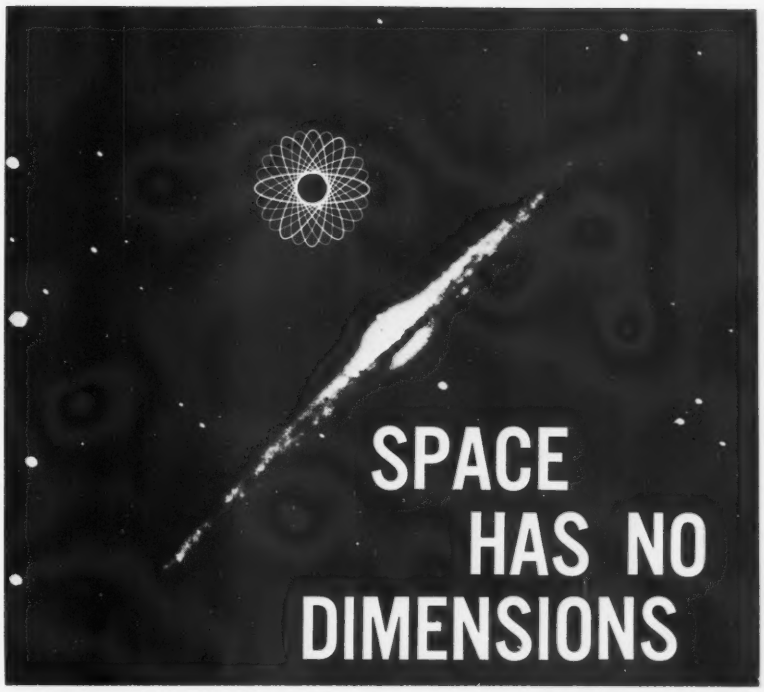
One airborne element of the CADL, the radar transponder, has interfaces with only the accessory power units and the antenna subsystem. The purpose of this unit is to enhance the tracking accuracy of surface-based, range-safety radars.

The glider test range contains the elements necessary to complete the CADL, test instrumentation, and range-safety subsystems. The major electronic components of the glider range are diagrammed on page 118. The range consists of a number of instrumentation sites, each of which has a particular configuration. CADL surface elements are located at nearly all sites. However, other subsystems vary considerably in composition.

Where relative physical location of the CADL and using subsystems requires surface communication facilities, these are supplied by the data-transmission system. Instrumentation radars operating in either the transponder interrogation or skin-tracking modes serve as the primary source of glider position data. CADL elements make use of radar-tracking information to steer its antennas, but also have the capability of self-tracking on the received signals. As a result of this self-tracking feature, CADL provides backup position data, but not to the same precision as that available from the radars.

Geographical dispersion of CADL and radar antennas leads to a requirement for spherical coordinate translation to correct antenna steering data for parallax. Such correction is supplied by the coordinate translation subsystem. In addition to steering-data correction, coordinate translation to a common reference is provided for supervisory control displays and impact predictions.

The CADL surface elements contain the complements to the airborne elements. The transmitted signals are received by tracking antennas, demodulated by low-noise receivers, and routed to the appropriate using subsystems. The demodulated PCM and FM subcarriers are routed, if needed, via the data-transmission subsystem to decommutators, subcarrier discriminators, and demultiplexers in the test-instrumentation subsystem. De-



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modulated pilot voice signals are fed into the voice network for distribution throughout the test-instrumentation and supervisory-control elements.

Test-conductor voice intended for the pilot is routed via the voice network from his console to the appropriate CADL site. Command data, which may be generated by local computation facilities, the local deputy test director, or facilities up range, is routed to the CADL location by the data-transmission facilities. Such data can be received in parallel or serial binary form at a wide range of bit rates. The data-multiplexing elements in CADL perform additional encoding and matrix the command data with the voice for transmission over a common surface-to-air radio link.

Two consoles are a part of the CADL surface group. The communication console displays the operational status of the receivers, transmitters, multiplexers, and antennas, and provides manual override on the automatic fail-over switching for redundant elements. The tracking console permits monitoring of antenna tracking performance, selection of tracking signal, and controls for manually assisting automatic signal acquisition.

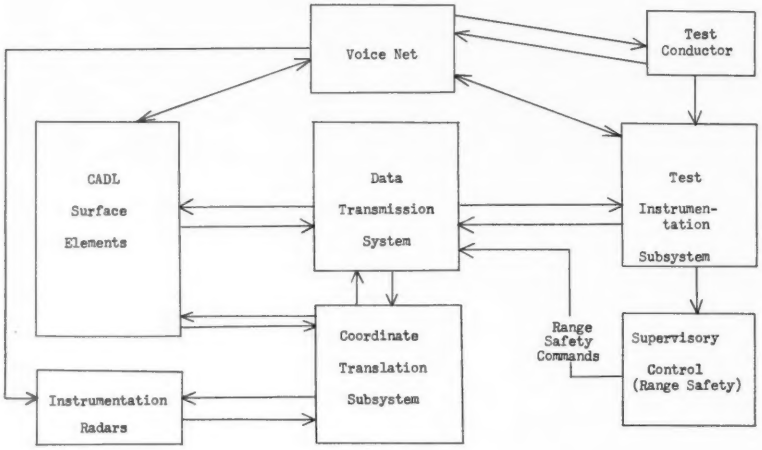
In addition to the obvious interface problems posed by the integration of additional communication equipment into an already crowded instrumentation range, there are several formidable factors which have influenced the design approach to the primary surface-air-surface transmission links. In fact, these factors have made necessary the design of some new equipment. Chief among the influencing factors are the following:

(a) Elevated skin temperatures
(b) Ionized shock wave
(c) Near orbital velocities with maneuvering capability
(d) Glider weight limitations

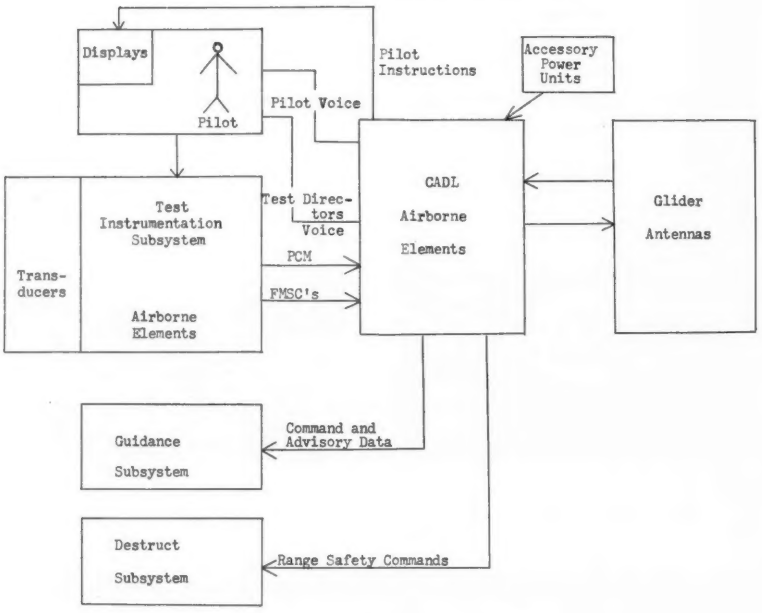
The elevated temperatures at the skin, for example, are conducted via the metallic portions of the RF conductors in the vehicle. Although advances have been made in building equipment for survival in high ambient temperatures, it appears that the problems have not been solved to the extent that direct connection between hot RF conductors and equipment is feasible for Dynasoar. Therefore, thermal isolation is required, and results in some absorption of the radio energy.

Another source of radio energy loss is in the dielectric window used to provide a hermetic seal while passing RF energy. High-temperature dielectrics in the antenna and in the thermal barrier will absorb between 20 and 30% of the RF signal. The worst offender within the glider, however, appears to be the metallic components themselves. Materials capable of providing adequate structural integrity in the temperature environment have a conduction loss approaching 40%.

CADL Ground Instrumentation



Major Airborne Subsystems Using CADL



Losses Apply Two Ways

These losses apply to both transmitted and received signals. Received energy is further degraded by electromagnetic noise energy that is emitted by the heated metallic and dielectric materials. Desensitization of the glider's radio receiver caused by such noise can be equivalent to a loss as high as 60% of the ground transmissions that are captured by the glider antenna.

To these losses are added the RF transmissibility of the ionized shock wave that surrounds the vehicle. This ionization is caused by the compression and heating of otherwise cool low-pressure gas. It has been known to cause loss of communication with nose cones during re-entry. The CADL problem is to maintain communication

during re-entry. A simple brute-force approach to such losses cannot be taken because of weight restrictions. As a result of painstaking efforts of many members of industry, NASA, and the Air Force, the Dynasoar System Program Office (AF) has chosen RF link characteristics that appear to be a good balance between finesse and brute force. Work to optimize the RF characteristics is being continued largely by Boeing Airplane Co., systems contractor.

Because of the weight limitations, very little of the additional link gain in the form of high transmitter powers and low-noise receivers can be allocated to the glider. Therefore, the surface elements of CADL make up this lack by high-gain transmitting and receiving devices on the surface. This leads to narrow-beam antennas that must be pointed at the vehicle, high-powered transmitters for the surface-to-air link, and low-noise receivers for the air-to-surface link.

The influence of the glider velocity, which has played the dominant role in creating the RF losses, now reappears in the form of an antenna tracking and an RF signal acquisition requirement. The problem of supplying antennas having the necessary dynamic response is currently under study, but appears feasible.

Along with these principal problem areas, RCA, other AF contractor associates, NASA, and the Air Force have examined or are examining in great detail the host of second-order and third-order problems that affect the design and utilization of the CADL subsystem. To date, the results have been most encouraging. ♦♦

Atlas-D Completes Development Testing

The 49th and last developmental Atlas-D missile was launched successfully January 23 from AMR, Cape Canaveral, bringing a 20-month Air Force proving program to a close. Of the Series-D launchings, the AF lists 35 as completely successful, eight as partially successful, and six as failures. Atlas-D will continue in service as an operational missile and as a space booster, but AF development testing at the Cape has now shifted entirely to Atlas-E. Atlas-D is scheduled as the booster for orbital launches in Project Mercury. The Convair-produced booster has, over-all, been scheduled for more than 100 launchings during the decade 1960–70 for NASA and AF satellite programs.

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Experimental Aerodynamics Course To Be Given at TCEA

The Training Center for Experimental Aerodynamics, Rhode-Saint-Genese, Belgium, has announced it is now accepting applications from graduate engineers and scientists for a one-year diploma course in experimental aerodynamics for the academic year Oct. 2, 1961 to June 30, 1962. There are no fees for this course and a number of student fellowships are available to cover travel and living expenses. Students are required to be fluent in either English or French; a condition of entry is citizenship of one of the nations of NATO.

The Center is an international educational institution under the chairmanship of Theodore von Karman, and possesses a well-equipped range of modern wind-tunnels in its laboratories near Brussels.

Further information and applications forms can be obtained from: The Director, Training Center for Experimental Aerodynamics, 72, chaussee de Waterloo, Rhode-Saint- Genese, Belgium.

SS-FM: A New Telemetry Technique for Wideband Data

Transmission capacity for vibration and other wideband data has been a problem in missile and space-vehicle development. A technique new to telemetry is being exploited in the solution of this problem by engineers at NASA's George C. Marshall Space Flight Center, Huntsville, Ala. It involves a data multiplexing system, designated SS-FM, that utilizes single sideband subcarriers on an FM carrier. SS-FM permits the transmission of approximately 45,000 cycles of data at an accuracy of 5% in the same RF bandwidth presently utilized by an FM-FM system with a capacity of 4000 cycles of data.

In addition to more than a tenfold improvement in bandwidth-utilization efficiency, up to 30-db improvement in signal-to-noise ratio is realizable. The first hardware utilizing the SS-FM technique is nearing completion for the Saturn program.

In the Saturn SS-FM system, the 45,000-cycle-bandwidth capability will be divided into 15 data channels, each with a response of 3000 cycles. However, the system is inherently flexible as to choice of data channel bandwidth. The SS-FM technique also lends itself quite readily to combinations with FM-FM, PAM, PDM, or PCM on the same carrier.

People in the News

(CONTINUED FROM PAGE 88)

dent and director of engineering, Avionics Div.

Ezra Kotcher has been appointed to form and manage a San Francisco Bay area office of Aerospace Corp. **Walter B. Brewer Jr.** has been made assistant general manager, Engineering Div.

Bertram Mintz has been appointed director of systems support in the recently expanded management team of Acoustica Div., Acoustica Associates, Inc.

Col. Guy B. Richardson Jr. (AF-Ret.) has joined General Precision, Inc., as special consultant to the president, D. W. Smith.

Richard T. Dale has been appointed works manager of Resistoflex Corp.

George E. Holmes has been placed in charge of Subroc and rocket production planning and control at Goodyear Aircraft Corp.'s Subroc Div., and will be assisted by **Henry H. Nettling,** who will be responsible for planning and processing functions.

Arnold L. Rustay has been elected a vice-president of Wyman-Gordon Co.

Louis Michelson has been named head of the Nimbus meteorological program for General Electric's Missile and Space Vehicle Dept., and **H. Herbert Jackson,** manager of the Nimbus control system.

George T. Scharffenberger has been promoted to executive vice-president of Litton Systems, Inc. He will continue as president of its Westrex division. **J. M. Bridgman** has been made vice-president and general manager of Litton Systems (Canada) Ltd., and **Victor V. R. Symonds,** contracts manager. **Ernest Wantuch** has been elected a vice-president of the Airtron Div.

Donald M. Allison Jr. has been named president of Vitro Electronics, a division of Vitro Corp. of America.

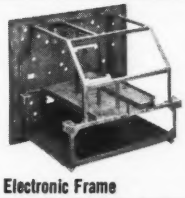
George B. Shaw, who heads the ACF Electronics Div., has been elected a vice-president of ACF Industries, Inc. **Harold T. Neal** has been appointed Paramus (N. J.) plant manager for the electronics division.

William Lawrence has been appointed general manager, San Diego facilities, General Dynamics/Electronics' Military Products Div, and **Howard L. Gates** as manager of operations. **Louis A. Carapella** has joined

TIROS Structure

Water Separator

Transmission Mount


Electronic Frame

Missile Support Cabinet

Photo courtesy Radio Corporation of America

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In the event of a change of address, it is necessary to include both your old and new addresses, as well as your membership number and coding, when notifying ARS Headquarters in order to insure prompt service. If you are moving or have moved, send the following form to Membership Dept., American Rocket Society, 500 Fifth Ave., New York 36, N.Y.

Name_____

Membership Card No._____ Coding_____

Old Address_____

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the Research Div. of GD/E. **Bernard B. Smyth** becomes assistant vice-president, General Atomic Div. of General Dynamics Corp.

Philip M. Brunstetter has been appointed to the new post of director, management development programs, Aerojet-General Corp.

Charles P. Bellican has been named vice-president, plans and programming, Decker Corp.

William E. Bradley has been appointed manager of the new Aero-Space Computer Section of Philco Corp.'s Computer Div.'s Systems Engineering Laboratory headed by Robert S. Senator.

Jan Al has been appointed director of the Dept. of Chemistry and Chemical Engineering, Southwest Research Institute.

Claude H. Smith has been appointed general manager, Minneapolis-Honeywell's Ordnance Div. facility, Duarte, Calif., and **Samuel D. Harper** as manager of a separate computer department in its Special Systems Div.

Claire Bell has joined Varian Associates as manager, instrument product engineering.

Alfred H. Canada has been named manager, engineering, Raytheon Co.'s Santa Barbara, Calif., operations.

Richard D. Moroney has been named project engineer for the G. T. Schjeldahl Co.

A. V. Gangnes and **J. F. Jenkins Jr.** have been appointed general manager and director of engineering, respectively, at Interstate Electronics Corp.

Harlan A. James has been appointed manager, Manufacturing Div., Pacific Automation Products.

L. R. Barr has been elected vice-president and general manager, Lear, Inc., and will direct the Lear-Romec Div.

Gen. Phillips W. Smith has been named a vice-president of Siegler Corp.

Leon E. Collier and **Michael Korek** have been appointed manager and assistant manager, respectively, military plans and programs, Loral Electronics Corp.

Choh-Yi Ang has been appointed manager of Telecomputing Corp.'s new Physics Research Laboratory; **Glen C. Danks,** corporate contracts administrator; and **William R. Bidermann,** chief production engineer, Whittaker Gyro Div.

Meyer Leifer has joined Ampex Corp. as chief engineer, Ampex Instrumentation Products Co.

Maurice A. Meyer and **Chester G. Kuczun** have been named vice-presidents of the Adcole Corp.

Louis B. Werner has joined Hazleton-Nuclear Science Corp. as vice-president.

G. Richard Tingley has been appointed vice-president, Military and Industrial Systems Dept., CBS Laboratories, while **Edward P. Laffie** has been named semiconductor quality control manager for CBS Electronics.

Sherrerd B. Welles has been appointed corporate director of engineering and research for Sanders Associates.

George L. Curtis and **Bogdan R. Stack** have been promoted to associate laboratory directors at ITT Federal Laboratories. **Wilbur S. Chaskin** has been upped to manager, engineering, ITT Kellogg carrier and microwave equipment manufacturing plant, Raleigh, N.C.

William K. Fortman has been named director of project engineering for Astrosonics, Inc.

Theodore Boxer and **Harold Jackson** have been named key managers in a new engineering group established at the Kollsman Instrument subsidiary of Standard Kollsman Industries.

Edmund M. Velten has been promoted to vice-president, production, Beryllium Corp.; **John R. Steele** has been named manager, Beryllium Metal Development; and **Arthur P. G. McGinnes Jr.,** manager, product development at BC.

ITT Licensed for Earth-Space Radio Experiments

Having received the first FCC license to private industry to operate a facility for earth-space communication research, ITT scientists swung this 40-ft antenna into operation recently at the ITT Federal Laboratories, Nutley, N.J. One object of research: Communication satellites. The FCC authorization, granted in January, runs for a year and is subject to renewal. It specifies operation at 2120 or 2299.5 mc until July 1, after which only 2299.5 mc may be used. Call letters for space: KFQXBR.

HONORS

Marcel J. E. Golay, consultant to Perkin-Elmer Corp. and Philco Corp., has received the 1961 American Chemical Society Award in Chemical Instrumentation for his significant contributions in gas chromatography, infrared spectrophotometry, and nuclear magnetic resonance spectrometry.

L. Eugene Root, corporate vice-president for missiles and electronics, Lockheed Aircraft Corp., was presented the Navy Distinguished Public Service Award "for his key role in the development of the Polaris missile."

Paul H. Reedy, president of Interstate Electronics Corp., also was a recipient of the Navy DPS Award for his active direction of the company which is prime contractor for Polaris test instrumentation. Interstate Electronics was awarded the Navy's Certificate of Merit for its role in the Polaris program.

Robert E. Supp, chief, Electrical and Advanced Propulsion Branch, Wright Air Development Div., has been presented the Air Force's Decoration for Exceptional Civilian Service.

Jerome B. Wiesner, President Kennedy's special assistant for science and technology, was named by the Electronic Industries Assn. to receive the 1961 EIA Medal of Honor for "distinguished service contributing to the advancement of the electronics industry." ♦♦

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PCM Telemetering

(CONTINUED FROM PAGE 45)

required to implement this concept. As a result of this redundancy, the amount of hardware required for all but a minimal-capability system is equal to or greater than the amount of hardware required for a system with a much greater capacity but possessing an optimum configuration. It is therefore believed preferable to design a programmer that is fixed in the quantity of hardware evolved. This system will be optimum from the standpoint of the amount of hardware required to achieve a maximum capability and will be flexible in that any format requiring less capacity can also be attained.

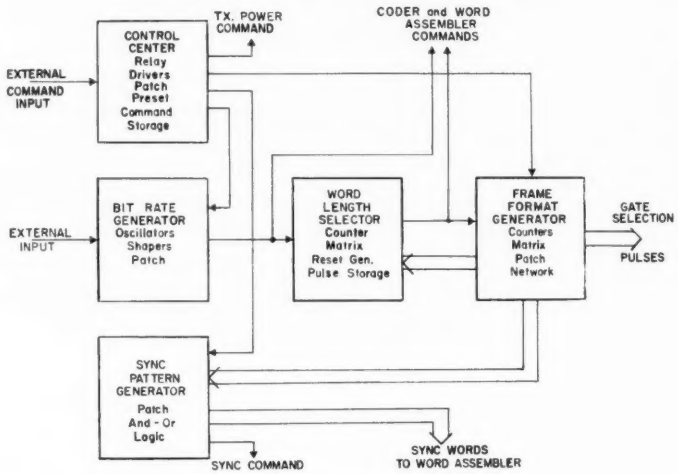
Variable word length will make it impossible to obtain symmetrical sampling of supercommutated channels in some cases without providing some "spacer bits" in the frame. Two choices are therefore possible. In some instances, a degree of asymmetry in the sampling may be tolerated. In other cases "spacer bits" will have to be added to provide a symmetrical sampling pattern tolerating the reduction in transmission efficiency. In many instances the assignment of the other prime channel time slots can be made so that the spacer bits which must be added will only comprise a small percentage of the total frame time. This problem is not imposed by the hardware design, but is fundamental with the variable word length capability. The decision of how to handle the problem for specific applications is left to the discretion of the user.

Word sync is not feasible or necessary with the variable word length. To form a continuous serial PCM message train without the presence of parity or word sync bits between words requires that the A-D converter operate at a higher rate than the system bit rate. The last bit of the previous word may then be stored and readout while the A-D converter is recycled to begin encoding the next analog sample. The A-D converter is asynchronous operating at a fixed rate which is higher than the 250-kc maximum bit rate.

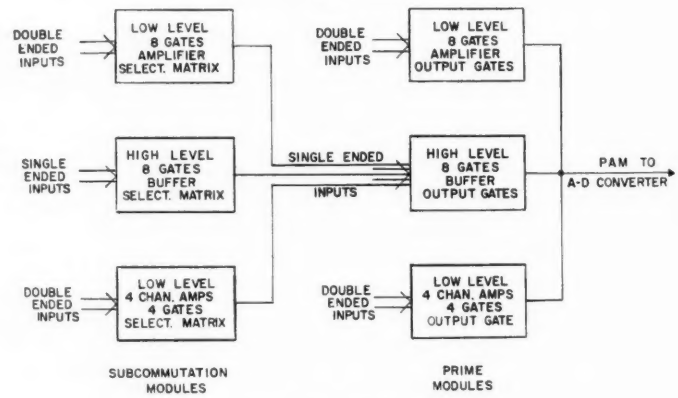
The drawing on page 45 shows the basic system block diagram. The system is conventional at this level. The special features of the system are embodied in the design of the individual subsystems. A block diagram of the programmer, one of these subsystems, is shown, top right. The main functional sections are a bit-rate generator, synchronization-pattern generator, word-length selector, frame-format generator, and the system command. Basic timing for the system may be derived from either external or internal clock rates. A patch network including bit-rate control circuitry has been provided. Thus, the bit rates for each phase of a mission may be selected by gating from preselected, patched rates.

The frame-format generator provides the gate-selection pulses, synchronization selection pulses, and inputs to the word-length selector. These pulses are obtained by counting down from the clock frequency, and formatting is achieved by selecting gating pulses of the desired frequency

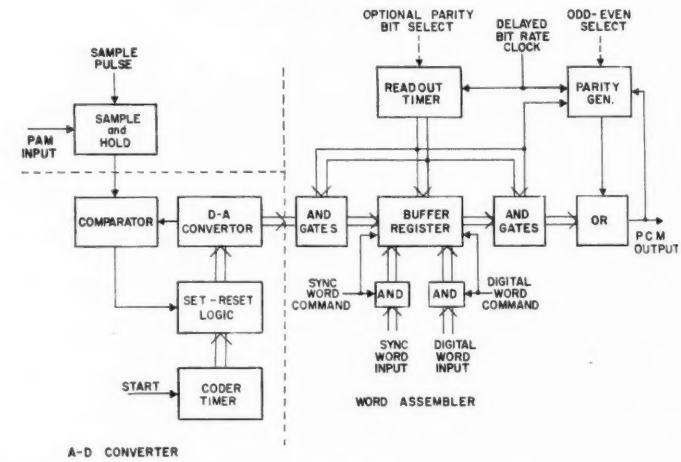
Adapt Subsystem Block Diagrams



Programmer


DOUBLE ENDED INPUTS
LOW LEVEL 8 GATES AMPLIFIER SELECT. MATRIX
LOW LEVEL 8 GATES AMPLIFIER OUTPUT GATES
SINGLE ENDED INPUTS
HIGH LEVEL 8 GATES BUFFER SELECT. MATRIX
SINGLE ENDED INPUTS
HIGH LEVEL 8 GATES BUFFER OUTPUT GATES
PAM TO A-D CONVERTER
LOW LEVEL 4 CHAN. AMPS 4 GATES SELECT. MATRIX
LOW LEVEL 4 CHAN. AMPS 4 GATES OUTPUT GATE
SUBCOMMUTATION MODULES
PRIME MODULES

Multiplexing System



Encoder

and phase. The main section of the generator, located within the master programmer module, contains binary counters and a transistorized pyramid matrix. The remainder of the format generator is contained in a subprogrammer module and in part of each subcommutator module used. Sampling rates from $^1/_4$ the word rate to $^1/_{4096}$ the word rate in steps of $^1/_4$ are available if the counters are not reset prior to the occurrence of the maximum count condition. Up to 64 prime channels (time slots) are available. For slower rates, subcommutation is accomplished by counting down and cascading segments of rectangular matrices which are located in each multiplexer module. Format control and word-length selection are available for prime time slots or slots at higher rates, and are achieved by providing alternate routes through the matrix to the output connections for each format.

Word Length Variable

Word-length selection has been provided in this design. A matrix attached to the bit-per-word counter signals the reset generator to reset the counter whenever coincidence between the counter and feedback pulses from the frame-format generator occurs. Patching of OR gates with frame-format generator outputs determines the word length of each time slot of the prime frame.

Flexible PCM systems require optimum synchronization patterns. The length of the pattern must be controlled according to the length of the data cycle. There are indications that optimum synchronization patterns of various lengths are not related to each other simply in that the longer pattern directly repeats the shorter pattern. Consequently, control of pattern length, pattern arrangement, and pattern selection for the phases of a mission are provided. Two pattern generators are required, because both synchronization of the prime frame cycle from bit rate and synchronization of the total data cycle from bits within the subcommutated cycle are required by IRIG specifications.

A block diagram of the multiplexer is shown on page 124. A choice of hi-level and low-level gates is provided. The hi-level gates are in modular units of eight gates per module. A common output is provided through a unity gain buffer. Two choices exist for low-level inputs. One modular unit contains eight low-level gates with a common-channel amplifier at the output. The other modular unit consists of four hi-level gates, each with its own channel preamplifier. Selection is made according to the requirements of the particular channels involved, and these modular units are cascaded in pyramid fashion to obtain a single common PAM output line that is fed to the sample-and-hold circuit of the encoder.

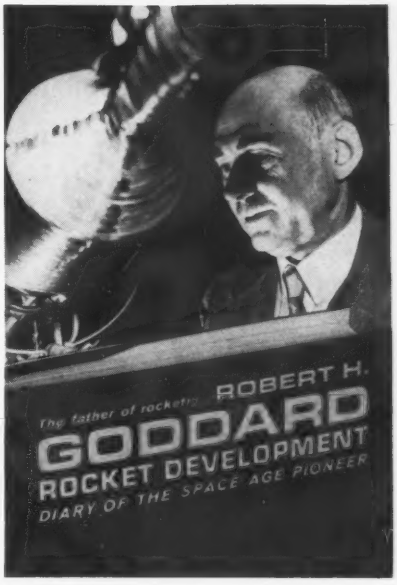
A block diagram of the encoder is also shown on page 124. The three major elements of the encoder are the sample-and-hold circuit, a 10-bit A to D converter, and a word assembler. The A-D converter is of the half-split type and is asynchronous, operating at a fixed 333-kc continuous variable word length, though the PCM message train varies in bit rate up to 250 kc. The converter rate is maintained constant to minimize the holding time required of the sample-and-hold circuit. Provision for either parity (even or odd) or no parity has been made.

The word assembler consists of a 10-bit buffer-storage register, a readout timer, and input and output gating circuitry. Information from the D-A Converter is read into this buffer in staggered parallel fashion. Sync words may be generated internally or introduced externally. Sync and digital words are read into the buffer register broadside. The serial PCM message train is then generated by sequentially scanning the contents of the buffer register with staggered parallel output pulses, supplied by the readout timer, and OR-gating the staggered parallel output.

The transmitter is turnable over the 215–260-mc telemetry band. Output power is programmable and can be varied from 8 to 200 w. The results of our analysis indicate that coherent phase modulation is superior to any other form of modulation, and in comparison to the incoherent frequency modulation (FM) for PCM data transmission, the factor of improvement is estimated at 6 to 12 db. A balanced modulator has been developed. The return-to-zero modulator drive provides a modulating waveform shaped such that the modulator output for each bit is identical. The result is a suppressed carrier (double sideband) amplitude modulation.

The value and flexibility of the Adapt system for far-space data acquisition lies in its control and range of available settings for transmitter power, bit rate, and acquisition format. Our studies indicate, moreover, that, while equipment flexibility is desirable, necessary compromises must be made with over-all complexity to maintain a reasonable degree of reliability.

Future work needs to be concentrated on improvement of multiplexers, optimization of transmitter efficiency over a range of power output, and coherent detection techniques for the modulation presented. ♦♦



"A mine of ideas for rocket, jet propulsion and space flight engineers and scientists for years to come"—

From Foreword by Harry F. Guggenheim

No list of great American scientists and inventors could rightfully omit the name of Robert H. Goddard. He was the father of modern rocketry, and this book is his own record of his most fruitful period of experimentation: 1929–1941.

He began his rocket research in 1909 building solid fuel rockets, but by 1920, he realized that the fuels of that time were inadequate for his purposes, and he undertook the task of developing a liquid rocket propellant. On March 16, 1926, in Massachusetts, he fired an odd-looking contraption that attained a speed of little more than sixty miles an hour and fell about 180 yards from its launching site. Hardly noteworthy by today's standards, but that was the world's first firing of a liquid-propellant rocket!

In 1930 he set up a testing ground in New Mexico near the site of today's White Sands Missile Range. Here he did his most productive work and wrote this book, which is a condensation of his scientific log—complete with many personal touches that have been kept intact.

As a record of the beginning of the rocket era, in the words of the man who ushered it in, this book is an incomparable historic document. As a scientific work its value is obvious, since Goddard's New Mexico period gave birth to the breakthroughs and discoveries that have placed men on the threshold of outer space today . . . liquid fuels, gyroscopic guidance systems, remote control, variable thrust devices and turbine driven pumps.

Rocket Development, edited by Esther C. Goddard and C. Edward Pendray, is 5½ x 8 inches in format, 222 pages and illustrated. A paper bound edition is also available at your bookstore. You may order the cloth bound edition of this March, 1961 publication by filling in and mailing the coupon below.

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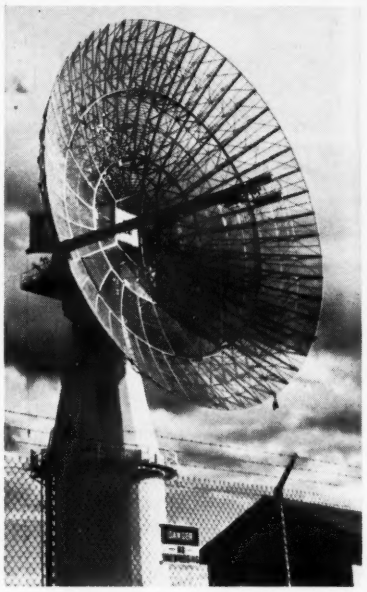
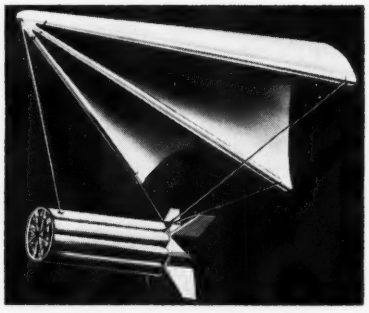
New Antenna For ARGMA

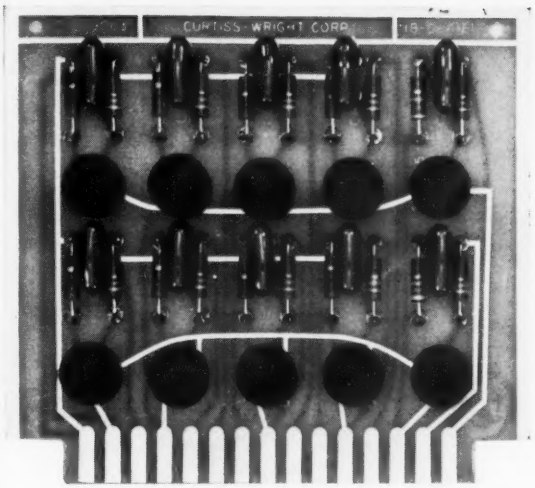


An 84-ft paraboloidal antenna, similar to the one pictured, of MIT Lincoln Laboratories' installation at Millstone Hill, Mass., is being built by the D. S. Kennedy Co. for the Army Rocket and Guided Missile Agency. The antenna will be used initially for tracking artificial satellites and for research in radio wave propagation. Plans call for the addition of radar equipment at the site to support a worldwide Zeus system.

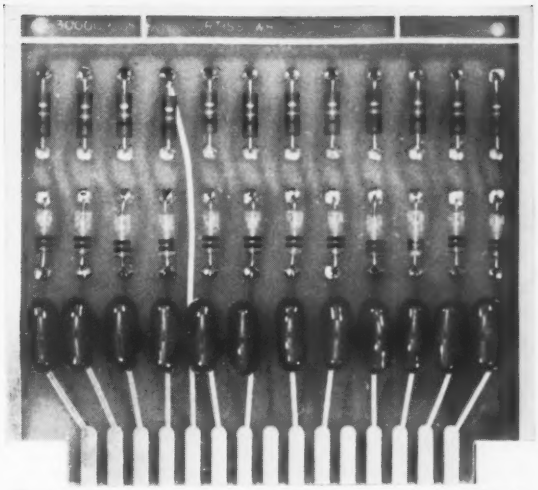
Paraglider Studied For Saturn Booster



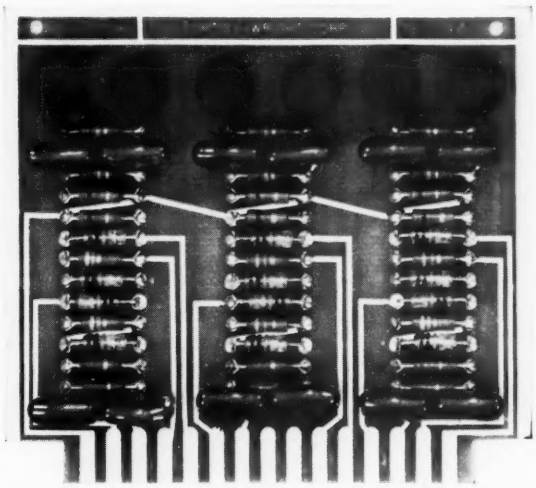
The Sketch depicts flexible-wing-paraglider recovery of a Saturn booster after stage separation. North American Aviation and Ryan Aeronautical recently received $170,000 and $146,000 six-month contracts, respectively, to study the technical and economic feasibility of such a system for lowering the Saturn booster safely to dry land. Wing deployment, glide control, and landing will be important subsidiary parts of the over-all study.



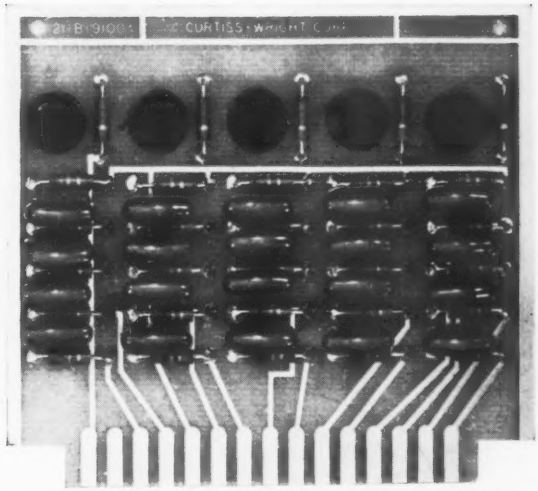
Two 4-Bit Transfer Gates (Actual Size)



Twelve Capacitor Input Diode Clamps (Actual Size)



Three Binary Circuits with Set-Reset Gates (Actual Size)



Five 4-Input NOR Gates (Actual Size)

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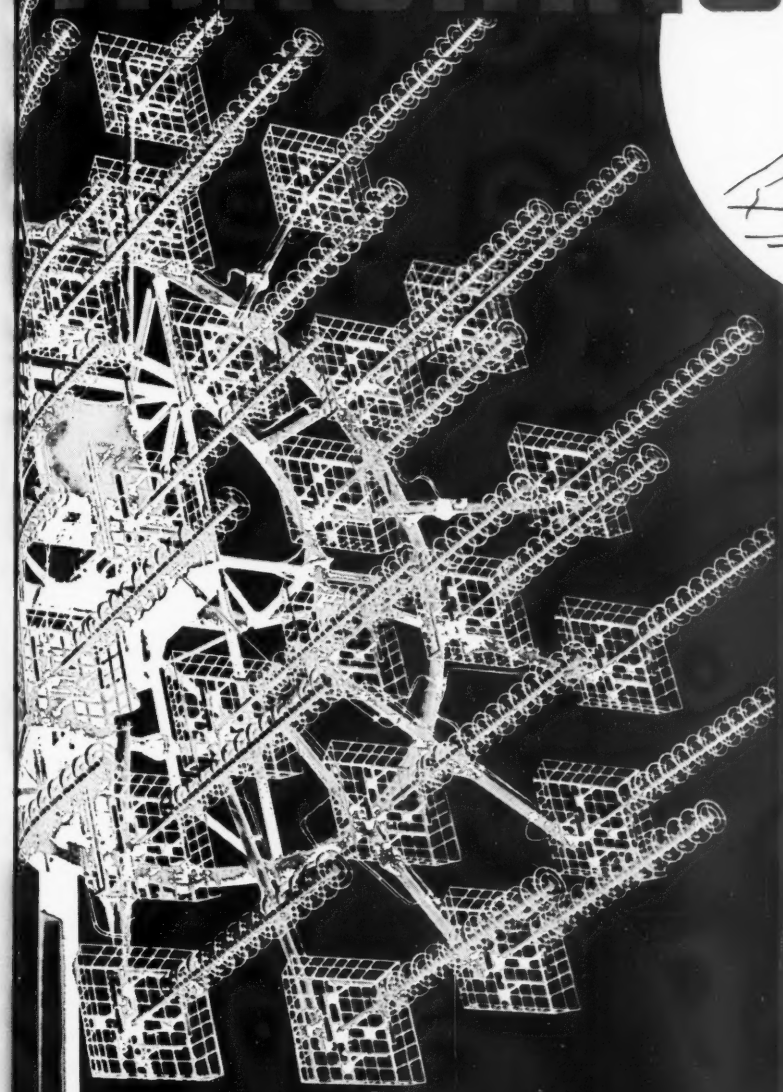

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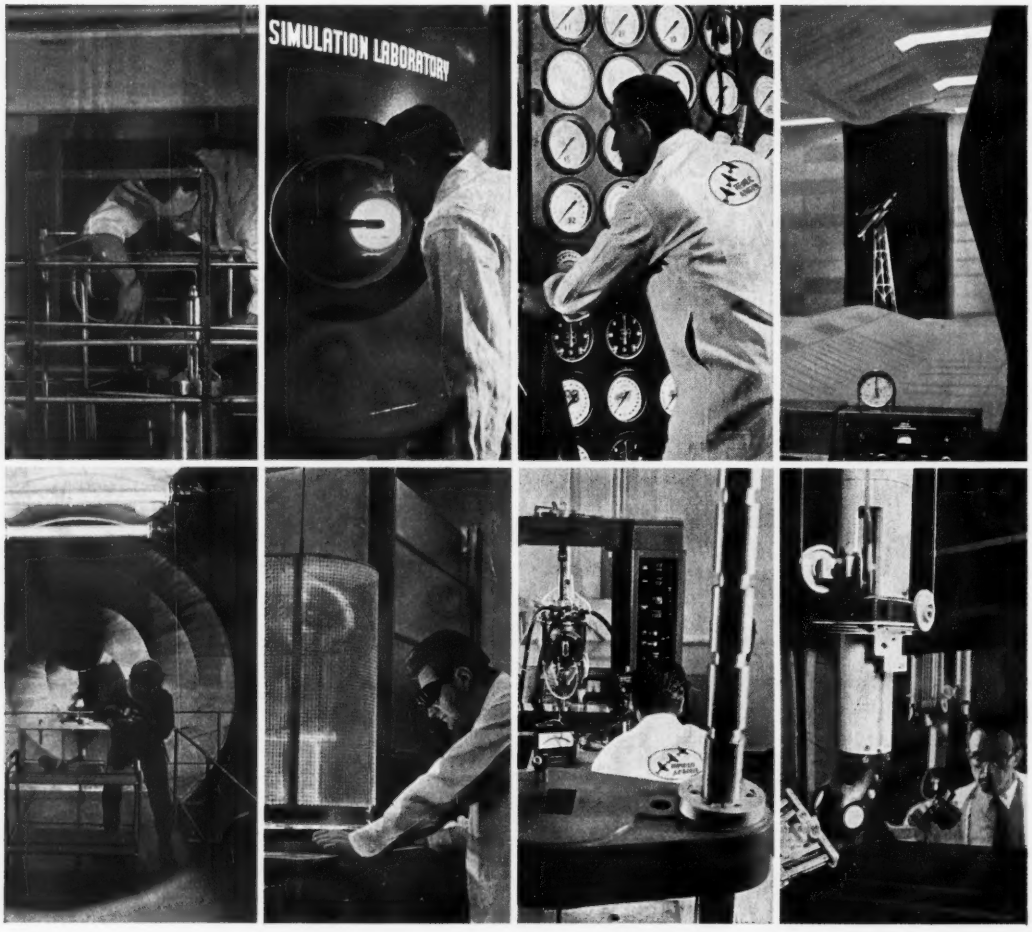

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